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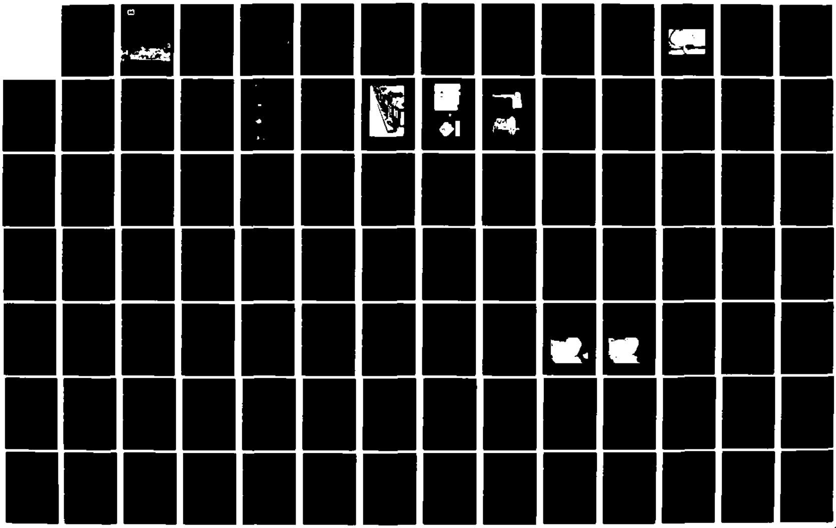

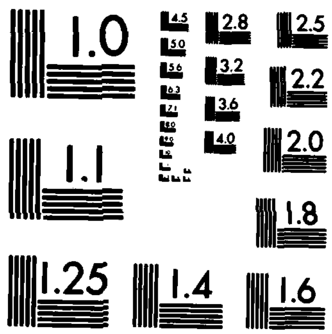

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TECHNICAL REPORT HL-82-16

PREVENTION OF SHOALING AT LITTLE LAKE HARBOR, MICHIGAN

Hydraulic Model Investigation

by

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July 1982

Final Report

Prepared for U. S. Army Engineer District, Detroit
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Little Lake Harbor, Michigan, was constructed as a harbor of refuge for small craft on the south shore of Lake Superior. However, the existing breakwaters have not prevented a heavy influx of sediment into the entrance channel and shoaling makes navigation difficult and dangerous. A 1:75-scale (undistorted) hydraulic model, reproducing the harbor, breakwater structures, entrance channel, adjacent shoreline for 1 mile both east and west of the harbor, and underwater contours out to -30 ft, was used to investigate various
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20. ABSTRACT (Continued)

plans proposed to minimize or eliminate channel shoaling. The model simulated wind waves, wave-generated currents, seiche action, seiche-generated currents, and the movement of sediment (by the use of a crushed coal tracer). From an analysis of prototype data on water-level variation in Lake Superior and the harbor basin, it was determined that seiche oscillations with periods near the inlet-bay Helmholtz period occurred frequently. These oscillations could generate velocities as high as 4.5 fps in the entrance channel, with a median velocity of 0.62 fps.

Proposed measures to reduce channel shoaling were primarily concerned with the addition of a new structure on the east side of the entrance channel and/or extensions of the existing breakwaters. From model test results it was concluded that:

a. When a plan extended through the existing intermediate bar which bypasses the harbor entrance, sediment tracer shoaled in the entrance channel.

b. If either the west or east breakwater protruded farther lakeward than the other, heavy channel shoaling usually occurred.

c. Of the plans tested, the Plan 8B configuration (a 570-ft-long, detached, dogleg breakwater on the east side of the existing entrance) was the optimum in minimizing sediment tracer movement into the channel from both the east and west at the least cost.

d. The gap between the new breakwater structure of Plan 8B and the shore would close due to sediment movement from the east, and the addition of a caisson to the lakeward terminus did not adversely impact shoaling patterns.

e. Plan 8B provided a straight-in approach for boat traffic into the protected area between the breakwaters.

f. Plan 8B reduced seiche oscillations in the harbor and velocities in the entrance (for the 0.5-hr period, 0.6 ft-seiche) when compared with the base conditions.

PREFACE

A request for a model investigation of Little Lake Harbor, Michigan, was initiated by the District Engineer, U. S. Army Engineer District, Detroit (NCE). The study was authorized by the Office, Chief of Engineers, U. S. Army, and funds for the U. S. Army Engineer Waterways Experiment Station (WES) to conduct the study were authorized by NCE on 14 June 1979.

The model study was conducted during the period January 1980-March 1981 under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory; Mr. F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory; Dr. R. W. Whalin, Chief of the Wave Dynamics Division; and Mr. C. E. Chatham, Jr., Chief of the Wave Processes Branch. Testing was performed by Messrs. E. F. Lane and J. W. McCoy, Engineering Technicians, with the assistance of Mr. G. Curry, cooperative education student trainee, and Mr. R. E. Ankeny, Electronics Technician, under the supervision of Mr. W. C. Seabergh, Project Engineer. Mr. K. A. Turner, Computer Specialist, provided assistance on the analysis of prototype data. This report was prepared by Messrs. Seabergh and McCoy.

During the course of the investigation, liaison was maintained with NCE by means of monthly progress reports, telephone communications, and conferences. The following personnel visited WES to observe model operation and participate in conferences during the course of the study:

Mr. Larry Hiipikka	North Central Division
Mr. Charlie Johnson	North Central Division
Mr. Tom Nuttle	Detroit District
Mr. Bob Elkin	Detroit District
Mr. Mark Grazzioli	Detroit District
Mr. Don Billmaier	Detroit District

Commanders and Directors of WES during the conduct of this study and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

". S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
feet per second	0.3048	metres per second
feet per second per second	0.3048	metres per second per second
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
square feet	0.09290304	square metres
square miles (U. S. statute)	2.589988	square kilometres
tons (2,000 lb, mass)	907.1847	kilograms

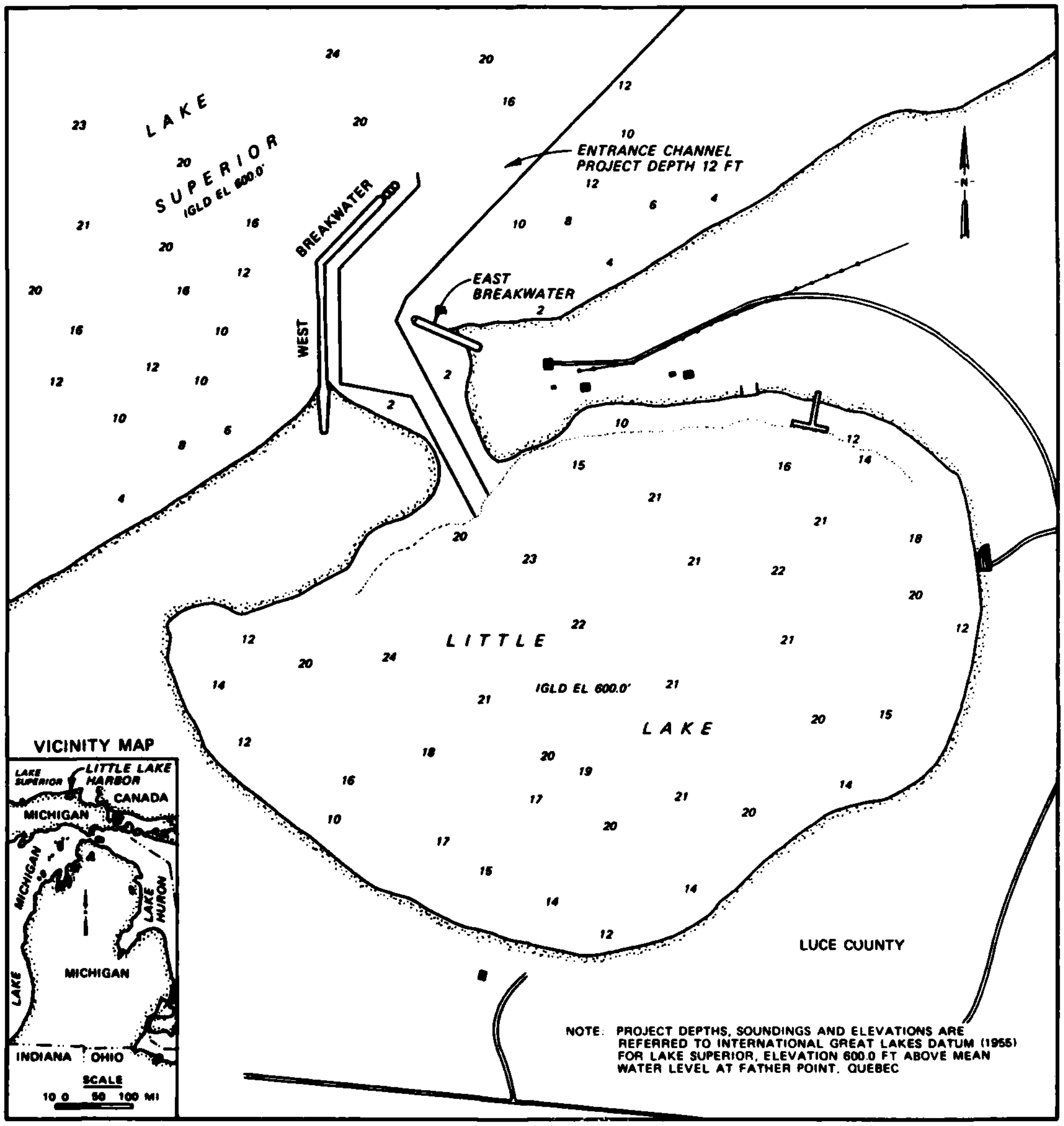

Figure 1. Little Lake Harbor

PREVENTION OF SHOALING AT LITTLE LAKE HARBOR, MICHIGAN

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. Little Lake Harbor is a harbor of refuge located on Lake Superior (Figure 1) about 21 miles* west of Whitefish Point and 30 miles east of Grand Marais, Michigan. The harbor is an important link in a chain of harbors along the south coast of Lake Superior that provide refuge from storms for light-draft vessels.

2. Originally, no permanent channel connected Little Lake with Lake Superior. Longshore sand movement usually closed off communication between the two bodies of water except when sufficient rainfall raised the water in Little Lake to cause a breach in the spit (U. S. Army Engineer District, Detroit, 1959). The original project (constructed between May 1962 and June 1964) consisted of two rubble-mound breakwaters, with the end of each terminated by steel sheet-pile cells to provide a safe and clearly defined entrance. The west breakwater was constructed at a crest elevation of +6.0 ft Low Water Datum (LWD) out to the then existing -6.0 ft LWD contour, and from this point the crest elevation was +8.0 ft to the lakeward terminus at the -12 ft LWD contour. Plate 1 shows typical breakwater cross sections. Total length of the west structure was 1,000 ft. The "dogleg" or angle change lakeward of the midpoint of the structure was effected to provide protection at the entrance from prevailing west, northwest, and north wave action. The length of the east breakwater was 270 ft. Channel design dimensions were 12 ft deep by 80 ft wide with the outer portion of the entrance channel flared toward the 12-ft depth contour to provide a wider entrance.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

The Problem

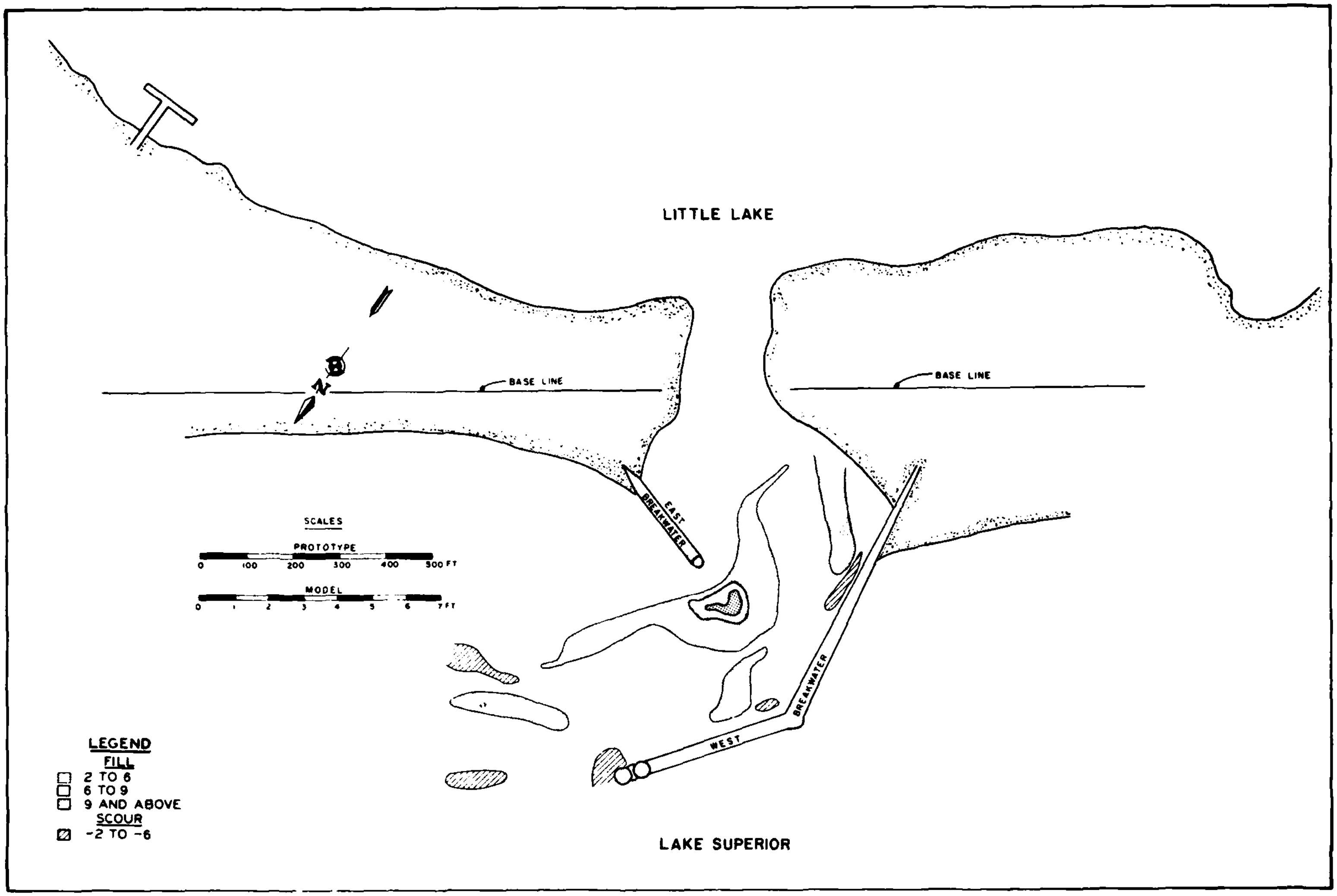
3. Severe shoaling occurs in the Little Lake Harbor entrance channel and required dredging has averaged 33,800 cu yd per year (U. S. Army Engineer District, Detroit, 1977). Plate 2 shows a recent bathymetry before dredging; Figure 2 shows the harbor and the shoal in the entrance channel in 1975; and Figures 3a and 3b show fill and scour maps for two recent time periods. All information indicates heavy shoaling on the eastern side of the channel between the two breakwaters. This heavy shoaling makes navigation to the protective harbor difficult if not dangerous even during relatively good weather conditions.

Figure 2. Little Lake Harbor, May 1975

The Dynamics of the Study Area

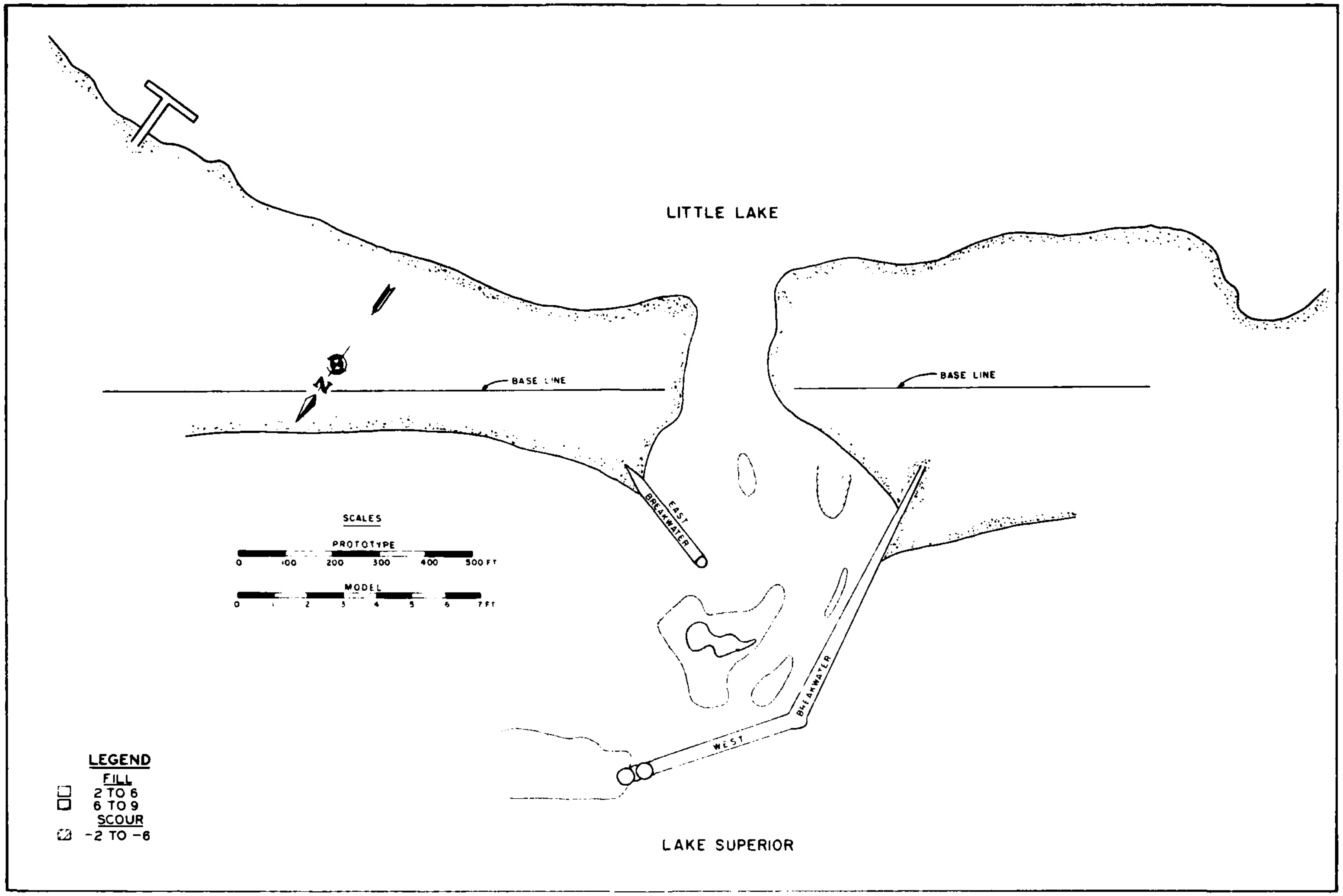
Sediment movement

4. As shown in Figures 3a and 3b, the heaviest shoaling occurs



a. July 1979-November 1979

Figure 3. Scour and fill (Continued)



b. November 1979-July 1980

Figure 3. (Concluded)

off the tip of the east breakwater. There appears to be continual movement of sediment into this region as noted from an examination of bathymetric surveys over the past 10 years and as has been visually observed since construction of the project. This sediment entering the channel at the east jetty location can presumably be derived from both upcoast and downcoast sources. Sediments migrating from west to east around the west jetty structure under the influence of wave- and wind-generated currents can move shoreward and become caught in a clockwise gyre in the lee of the west breakwater. This gyre has been documented in the fieldwork of Saylor (1966) and combined with the action of refracted and diffracted waves is able to move sediments toward the channel and cause shoaling. Also, any sediments that have been brought from east to west toward the entrance channel can be moved into the channel at this time even though wave conditions are occurring from the westerly directions.

5. When waves occur from the north to northeast, there appears to be a direct path of transport along the coast and into the channel with an abundant supply of sand being derived from the sand cliffs that have been historically eroding onto the beaches east of the harbor entrance (U. S. Army Engineer District, Detroit, 1977). Sediment transport through the west breakwater also has been noted that can cause minor shoaling on the west side of the channel. Occasionally, sand accumulates off the tip of the west breakwater as shown in Figure 3b but not in Figure 3a. Kureth (1978) estimates that of the total shoaling at Little Lake, 60 percent comes from the east and 40 percent comes from the west. Estimates of longshore sediment transport (U. S. Army Engineer District, Detroit, 1977) indicate that 77,000 cu yd annually moves east and 32,000 cu yd moves west.

6. Offshore bars are of importance in the patterns of sediment movement near Little Lake Harbor. Fieldwork by Bajorunas and Duane (1967) and Saylor and Upchurch (1970) point out the existence of a multibar morphology characterized by an inner bar (crest at 2-ft depth), an intermediate bar (4- to 6-ft depth), and a deepwater bar (about 12- to 14-ft depth). Bars near the structures for the May 1979 survey had crests of 2 to 3 ft, 8 to 9 ft, and 17 to 18 ft. The two outer bars

were continuous, moving from west to east, past the harbor entrance. The shallow-water bar is variable in location and tends to move shoreward and weld to the shore during fair weather. The other two bars are more permanent features with respect to location. The 8- to 9-ft-deep intermediate bar is most likely an important avenue of bypassing sediment around the harbor during larger wave conditions.

Seiche activity

7. Another aspect of the dynamics of the Little Lake Harbor area relates to the occurrence of seiche activity in Lake Superior and the generation of currents through the Little Lake Harbor entrance channel and bay. Seiche currents of up to 5 fps can occur and influence sediment movement in the area by augmenting the gyre circulation patterns. This will be discussed in greater detail in PART III.

Proposed Improvements

8. A number of structural alternatives that would alleviate shoaling problems in the entrance channel were recommended by the Detroit District (U. S. Army Engineer District, Detroit, 1977). Of eight original alternatives, five were chosen for testing in the hydraulic model and are shown in Plates 3-7. As the study progressed, other alternatives were developed, especially in regard to minimizing costs.

Purpose of the Model Study

9. The model study was conducted to aid in development of the most economical plan that would minimize channel shoaling without adversely impacting navigation.

PART II: THE MODEL

Description

10. Little Lake Harbor model was constructed in a 150-ft-long by 120-ft-wide by 2-ft-deep concrete basin to a 1:75 (undistorted) scale. About 7,500 sq ft of model (representing 1.55 square miles, prototype) was molded with concrete mortar to aluminum templates that had a model spacing of 4 ft along the beachline and 2 ft in the region of the harbor entrance. Lake Superior contours were accurately molded to -30 ft LWD, with a sloping transition to the basin bottom at -66 ft LWD. About 1 mile of beachline both upcoast and downcoast of the harbor was modeled (Figure 4). Figure 5 shows the completed model. From the 1:75 geometric model scale, relations for various characteristics were computed based on the Froudian law of similitude as follows:

Characteristic	Scale Relations
Horizontal distance	$L_h = 1:75$
Vertical distance	$L_v = 1:75$
Volume	$L_h L_h L_v = 1:421,875$
Velocity	$L_v^{1/2} = 1:8.660$
Discharge	$L_v^{3/2} L_h = 1:48,714$
Time - long wave	$L_h / L_v^{1/2} = 1:8.660$
Time - wind wave	$L_v / L_v^{1/2} = 1:8.660$
Slope	$L_v / L_h = 1:1$

Model Appurtenances

11. The model was equipped with the necessary appurtenances to reproduce all required phenomena including water-surface fluctuations, waves, and wave-generated currents. Apparatus used in connection with

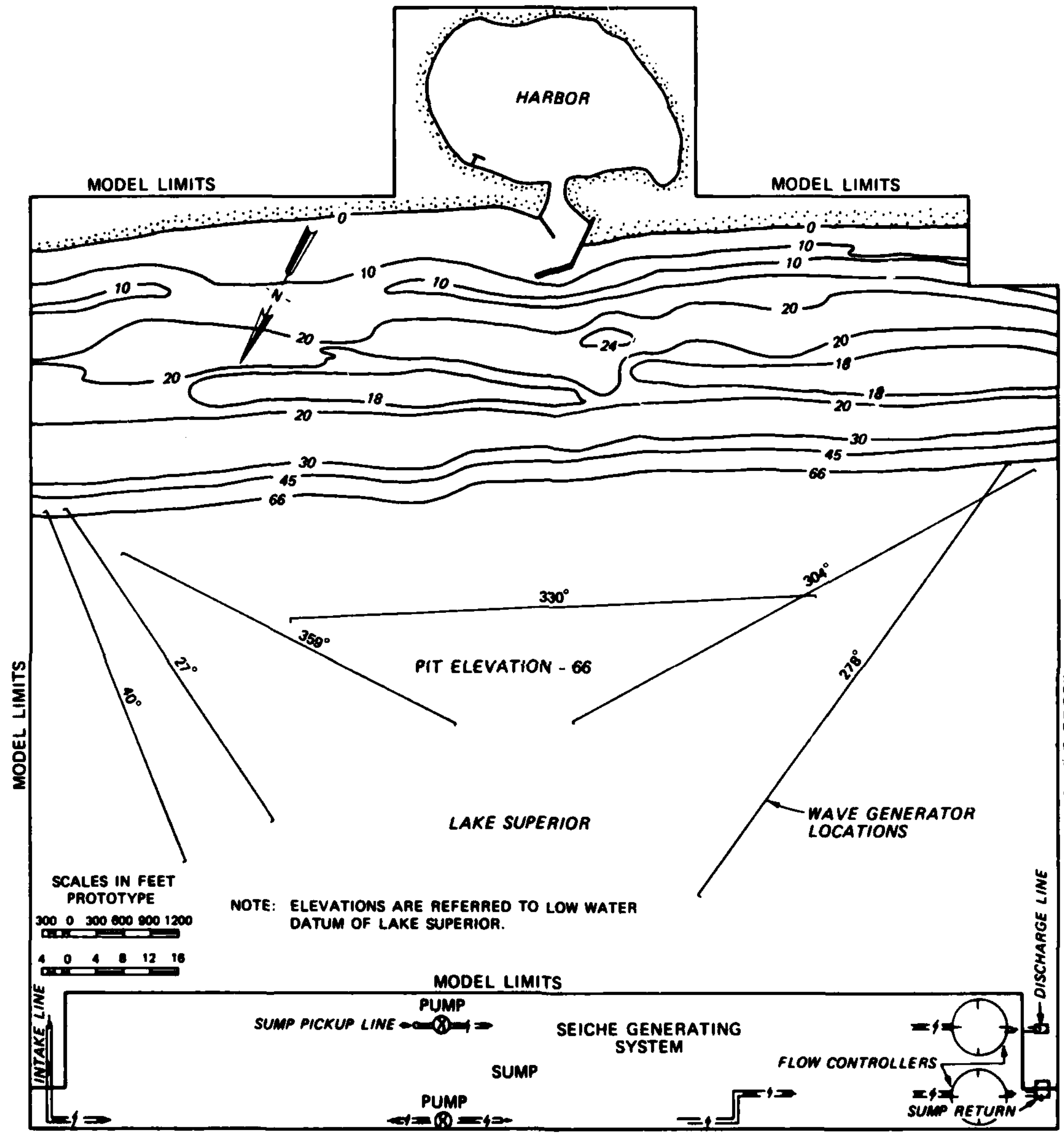


Figure 4. Model layout

Figure 5. Little Lake Harbor model

the reproduction of these phenomena included wave generators and a seiche generator. Wave action was reproduced in the model with 70- and 80-ft-long vertical-plunger-type wave generators (Figure 6) that could be quickly adjusted to reproduce the required wave height and period. The seiche generator, located as shown in Figure 4, consisted of two programmable flow controllers. These controllers operate under a constant pressure head and each contains a number of various sized calibrated orifices that may be opened or closed to produce varying flows. One controller removes water from the model and stores it in the sump while the other takes water from the sump and introduces it into the model. By programming a series of drum switches for each controller, a desired water-level rise and fall can be reproduced in the model.

12. Apparatus to measure current velocities, wave heights, and water-surface elevations are shown in Figures 7, 8, and 9, respectively. The current meters were miniature Price-type current meters with an electronic counter that tabulates the passage of each rotating cup by means of reflected light pulses transmitted by fiber optics to a photodiode. Usually a 10-sec counting period was used for each reading. Water surfaces were recorded with Leopold and Stevens water-level sensing transmitters located at the gaging stations in the model and companion recorders located in the instrument trailer. Also, portable point gages were used to measure water-surface elevations. Wave data were collected with the Automated Data Acquistion and Control System (ADACS). Through the use of a minicomputer, ADACS recorded onto magnetic tape the electrical output of parallel wire resistance type sensors as the water-surface elevation varied with time. The magnetic tape output of ADACS then was analyzed by the computer and tables of wave height were printed.

Figure 6. Wave generator

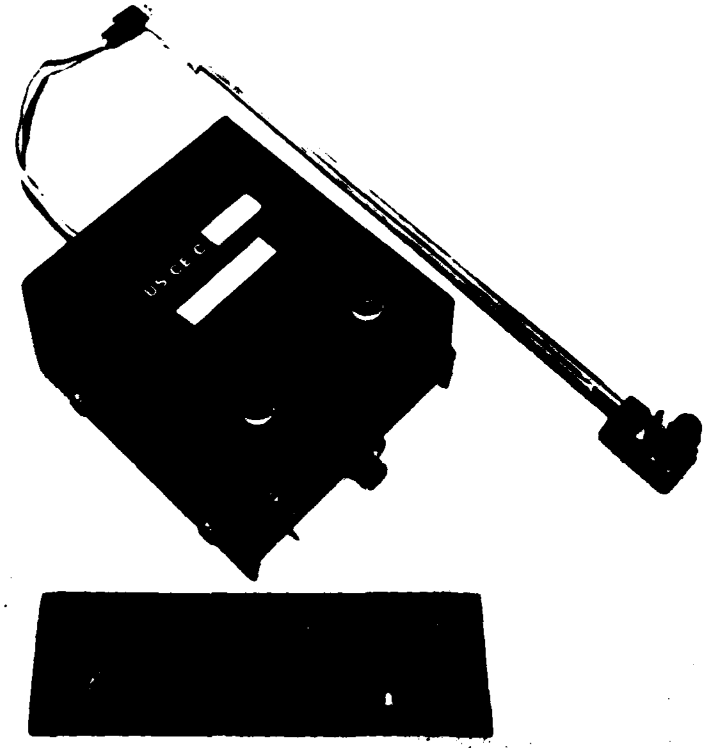


Figure 7. Current meter

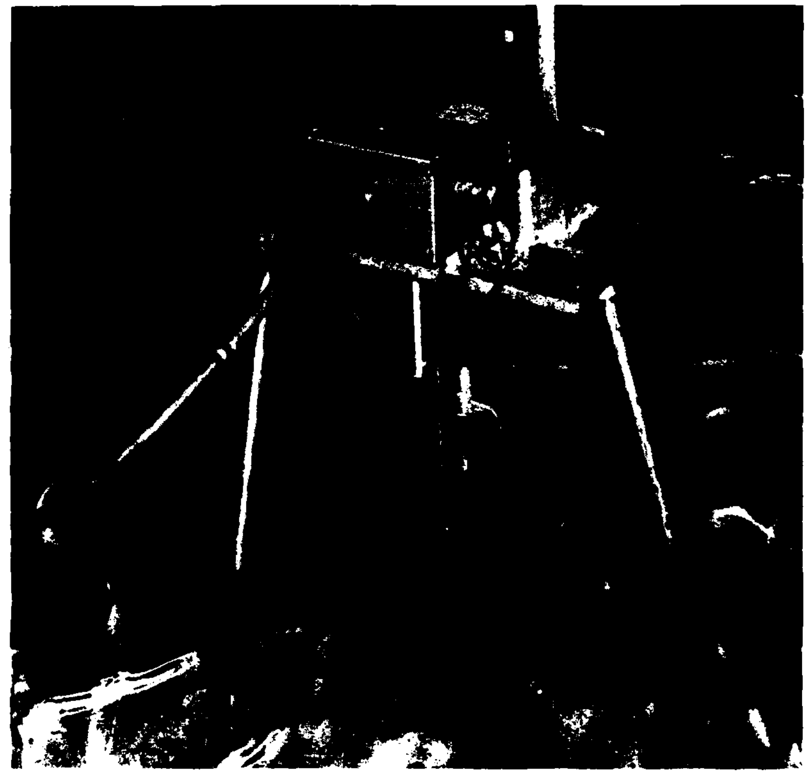
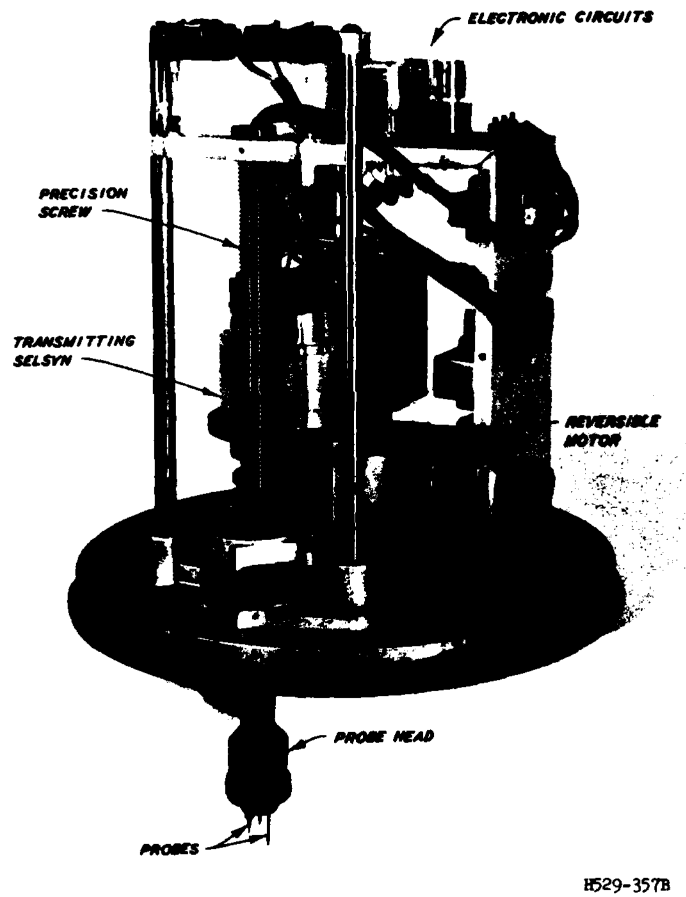


Figure 8. Wave rod



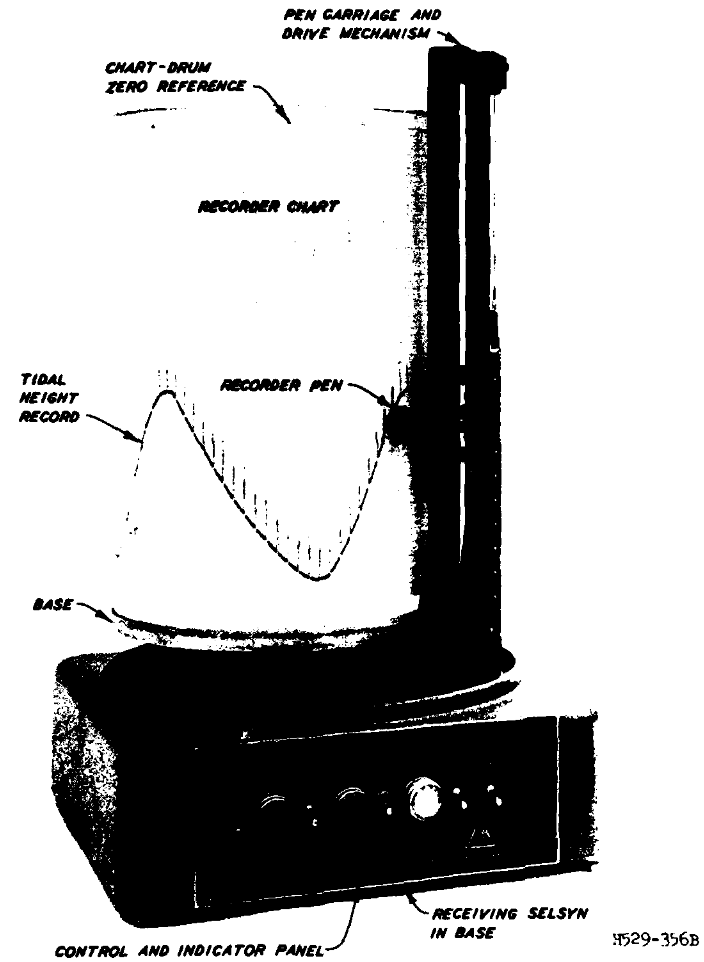


Figure 9. Water-level recorders

PART III: PROTOTYPE DATA AND MODEL TEST CONDITIONS

Water Levels

Mean level

13. Lake Superior has the least variation of water level in the Great Lakes. The maximum yearly fluctuation was 2.14 ft in 1968 and the minimum was 0.45 ft in 1929. LWD is 600.0 ft above IGLD (1955) at Father Point, Quebec. The mean water level is 601.0 ft IGLD or +1.0 ft above LWD. The mean water level was chosen as the only water level necessary for model testing due to the rather small fluctuations occurring at the project site.

Seiching

14. Short-term variations in the water level can be caused by seiching action. This has been well documented by Saylor (1966) and Seelig and Sorensen (1977). Lake Superior is subjected to wind stresses that are applied and removed as the winds vary in duration, magnitude, and direction. The lake responds to these forces with water-level variation. As the forces are gradually reduced or changed, oscillations of water level can occur with various frequencies and amplitudes dependent on the shape and bathymetry of the lake and the direction, duration, and magnitude of the wind stresses. Fluctuation of the lake level can then induce currents through an entrance channel to an embayment. Bayward flowing currents enter the basin through the channel as the lake oscillation increases in amplitude along the shoreline, then water empties through the channel lakeward as the lake level recedes. Normally, if the surface area of the bay is small relative to the entrance channel area, currents will be small. However, if the inlet-bay system is subjected to a seiche frequency near that of the Helmholtz frequency (which is defined by a function of the channel length and width, bay area, channel area and depth, and which has a period longer than the fundamental mode of the basin that is estimated by the Merian formula), resonance may occur and water-level fluctuations in the bay can be greater than those of the forcing system in the lake. This amplification is the

result of the inlet channel water mass and the rise and fall of the bay acting together as a spring-mass system. The frictionless-inlet-bay Helmholtz *period* $T_{h'}$, is found from Miles (1948) as:

$$T_{h'} = 2\pi \sqrt{\frac{(L + L')A_{bay}}{gA_c}}$$

with L' , an added channel length, defined by

$$L' = \frac{-B}{\pi} \ln \frac{\pi B}{\sqrt{gd}\; T_{h'}}$$

where

L = channel length (1,000 ft)
A_{bay} = surface area of bay (4.2×10^6 sq ft)
A_c = cross-sectional area of channel (1,988 sq ft)
g = acceleration due to gravity (32.2 ft/sec^2)
B = width of channel (270 ft)
d = depth of channel (7.4 ft)

An iterative solution of the above equations indicates a Helmholtz period for Little Lake Harbor on the order of 31 min when reasonable values of the above-defined parameters (for the 1979 prototype conditions) are substituted into the equations. Therefore, when lake water-surface oscillations are of this frequency, resonance of the bay-channel system can occur and as a result, significant velocities can occur in the entrance channel region as shown in Plate 8 from Seelig and Sorensen (1977) which was based on a seiche amplitude of 0.1 ft. Their analysis, based on June 1975 hydrographic conditions, and using a numerical model that included friction, resulted in a period of 36 min for maximum amplification. Solving the Miles equation resulted in a period of 36 min for the 1975 hydrography. Another analysis using the Hybrid Finite Element Technique performed at WES for the 1979 hydrography predicted resonance at a 35-min period. This assumed a frictionless system with radiation losses.

15. In order to determine the occurrence of seiching and its

magnitude near Little Lake Harbor, two water-level recorders were installed by the Detroit District in April 1979. One was located at the lakeward end of the west breakwater and one at the boat dock in the harbor. These recorders sampled elevations every 5 min on punched paper tape. The punched tape then was read and the data were stored on magnetic tape. This data then could be plotted (see Figure 10) or subjected to spectral analyses, which is a statistical procedure for determining the frequency components of a time series. Using a sampling rate of 5 min (0.083 hr), the maximum frequency for which the analysis provides information is given by the Nyquist frequency, $f_n = (2t)^{-1}$ and is 0.00166 Hz (0.1 cycle per minute or 6 cycles per hour or a period of 10 min). Also, the data were filtered and periods less than 13.6 min and greater than 2.5 hr were removed. Periods outside this range were not of importance for the analysis of seiche currents as shown in Plate 8. Therefore, aliasing, or the transfer of energy from the high frequencies to lower frequencies, should not introduce any difficulty in this study.

16. Water-surface elevation data for each gage were broken down into groups of 256 continuous data points (21.25-hr duration record). Although continuous segments of the records were much longer than this duration, it was felt that this was the appropriate record length to use in order to maintain weak stationarity of the seiche-generating conditions. Spectral analysis of the water-level data was then performed using a Fourier Transform.

17. Table 1 shows the various times at which data were analyzed. Data were divided into sets based on times when both gages were operative and producing good data. For other portions of the analysis of seiche activity, a total of up to 187 days were included in the analysis. Figure 11 shows the results of the spectral analysis for 12 June 1979 for the lake gage and the dock gage. Amplification of the various frequency components in the 0.6 to 2.6 cycles per hour (cph) range (which existed for this given day) can be noted and are plotted for all frequencies analyzed in Figure 12. It should be noted again that the low frequencies (below 0.40 cph) and high frequencies (above 4.40 cph) have

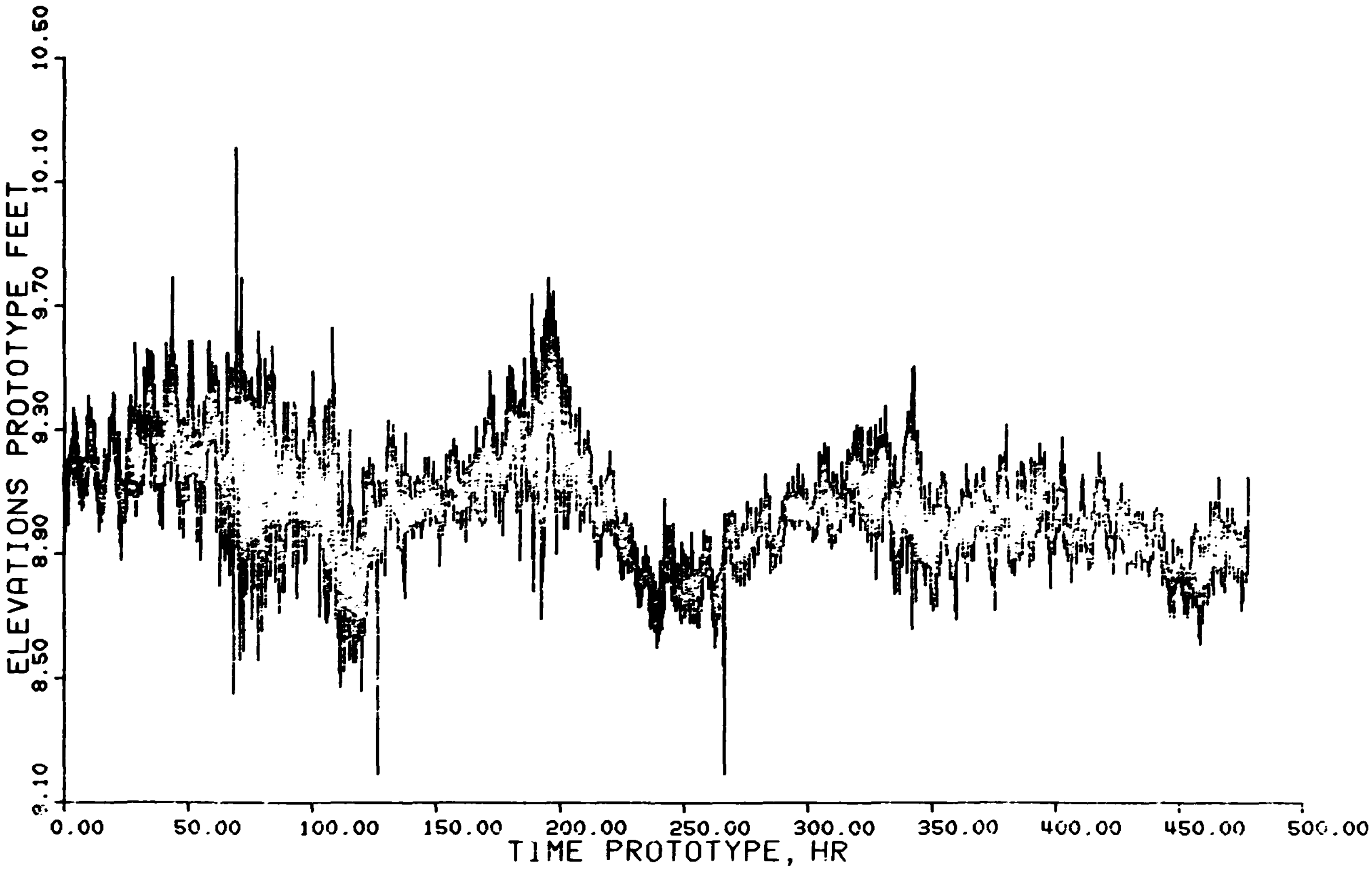


Figure 10. Lake water-surface elevation versus time, starting 12 June 1979, at 1040 hr

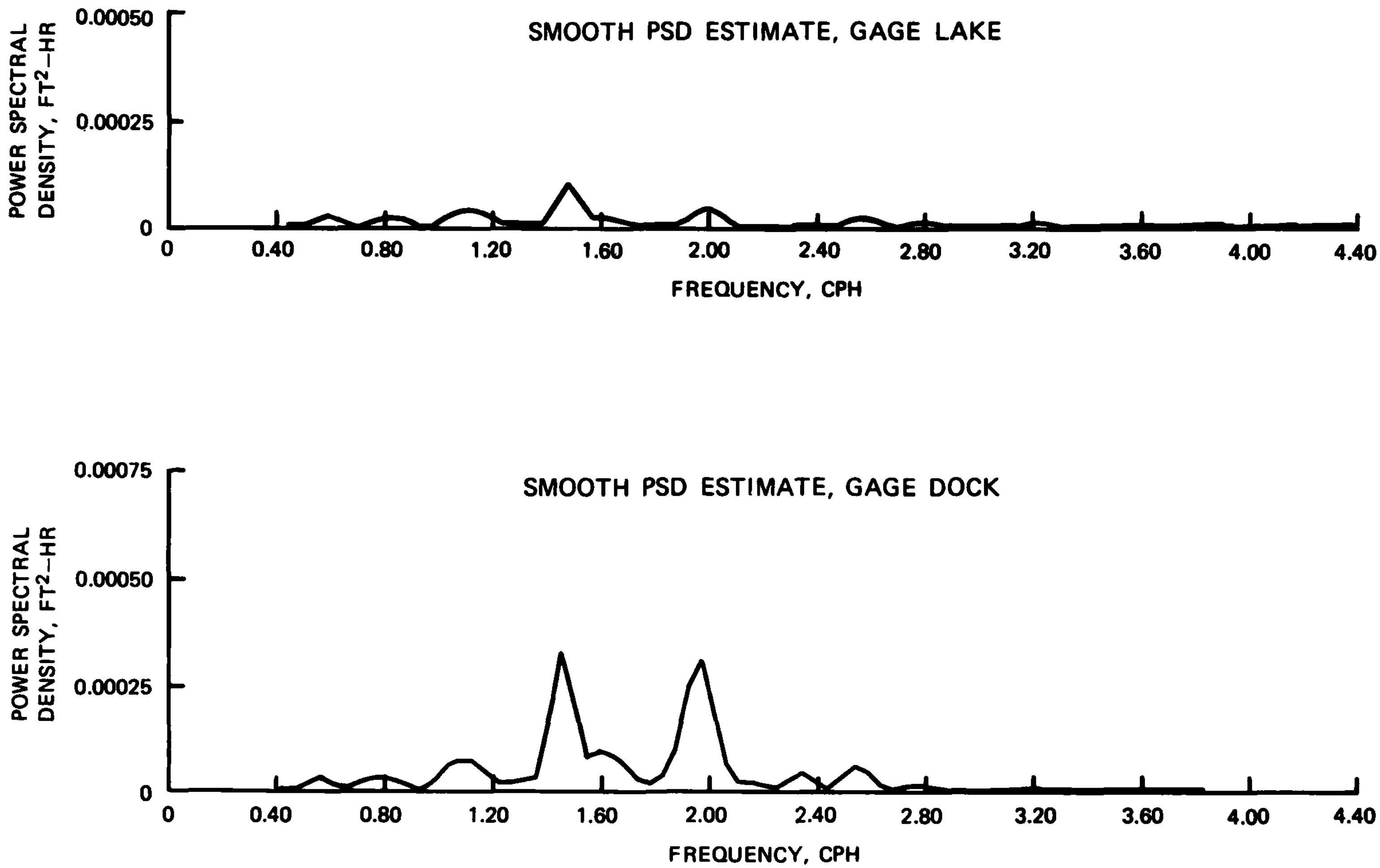


Figure 11. Power spectral density, 12 June 1979

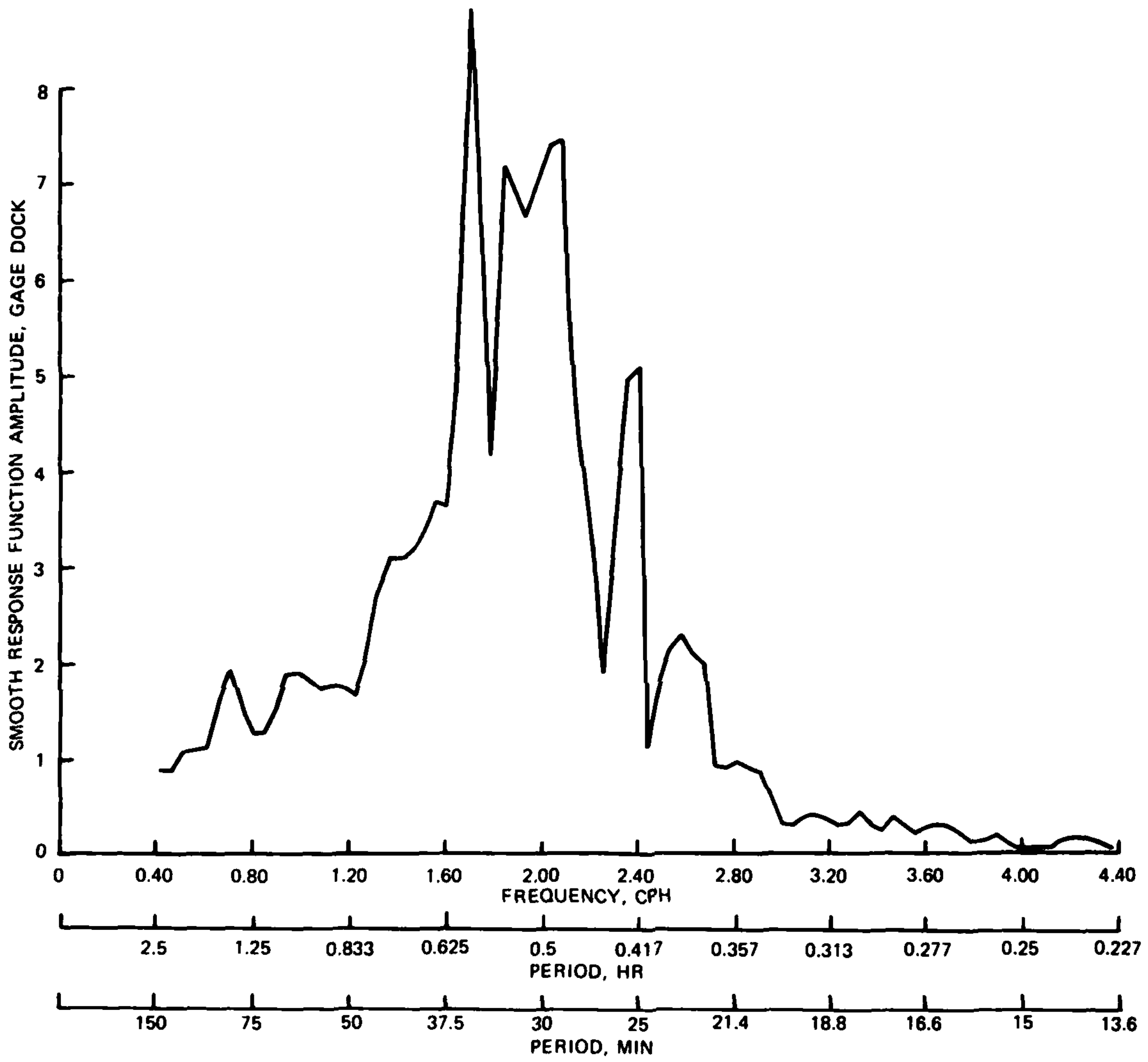


Figure 12. Amplitude response, dock divided by lake, 12 June 1979

been filtered out due to the primary interest in the frequencies which remain and which cause the most effect due to the Helmholtz pumping mode. Plate 9 shows a power spectral density distribution before filtering. Energy at the lower frequencies, e.g., 8.1 hr, do not significantly contribute to the generation of currents at the harbor.

18. Table 2 shows the modes of oscillation of Lake Superior (taken from Seelig and Sorensen (1977), who derived the data from many sources). Comparison of these frequencies with those occurring in Figure 12 (which indicates those frequencies being amplified by the harbor resonance) shows that about 0.6 to 2.6 cph is in the range of the higher modes of longitudinal oscillation and some transverse modes of oscillation of Lake Superior. An examination of all the analyzed data (not all data are shown in this report but are on file at WES) reveals energy peaks at 0.56, 0.86, 1.46, 1.96, 2.08, 2.5, and 2.9 cph. Maximum lake energy frequencies are usually 1.46 cph or less, but occasionally can be as low as 0.56 cph or as high as 1.96 cph. Frequency of maximum energy at the dock gage is usually 1.96 cph but this can depend on the range of frequencies in the lake, which tend toward the lower range of frequencies. The 1.96-cph frequency corresponds to a period of 0.51 hr or 30.6 min which is close to the calculated Helmholtz period of 31 min. Since there are frequencies in this range normally near Little Lake Harbor, seiching activity can be expected to induce significant velocities in the entrance channel. The amplitude amplification curve for Little Lake and the expected velocities for a 0.1-ft amplitude monochromatic seiche for a range of periods shown in Plate 8 again illustrate the points discussed above.

19. Examination of Figure 13 for 15 June 1979 shows that there is significantly more energy existing in the lake and higher energy levels in the harbor over a broader range of frequencies than existed on 12 June 1979 (Figure 11). Figure 14 shows a plot of the actual water-level variation in the lake and in the harbor for these two time periods. The 12 June 1979 data show that the harbor is near resonance since the range of water-level variation is greater in the harbor than in the lake. The 15 June 1979 data indicate greater height variation

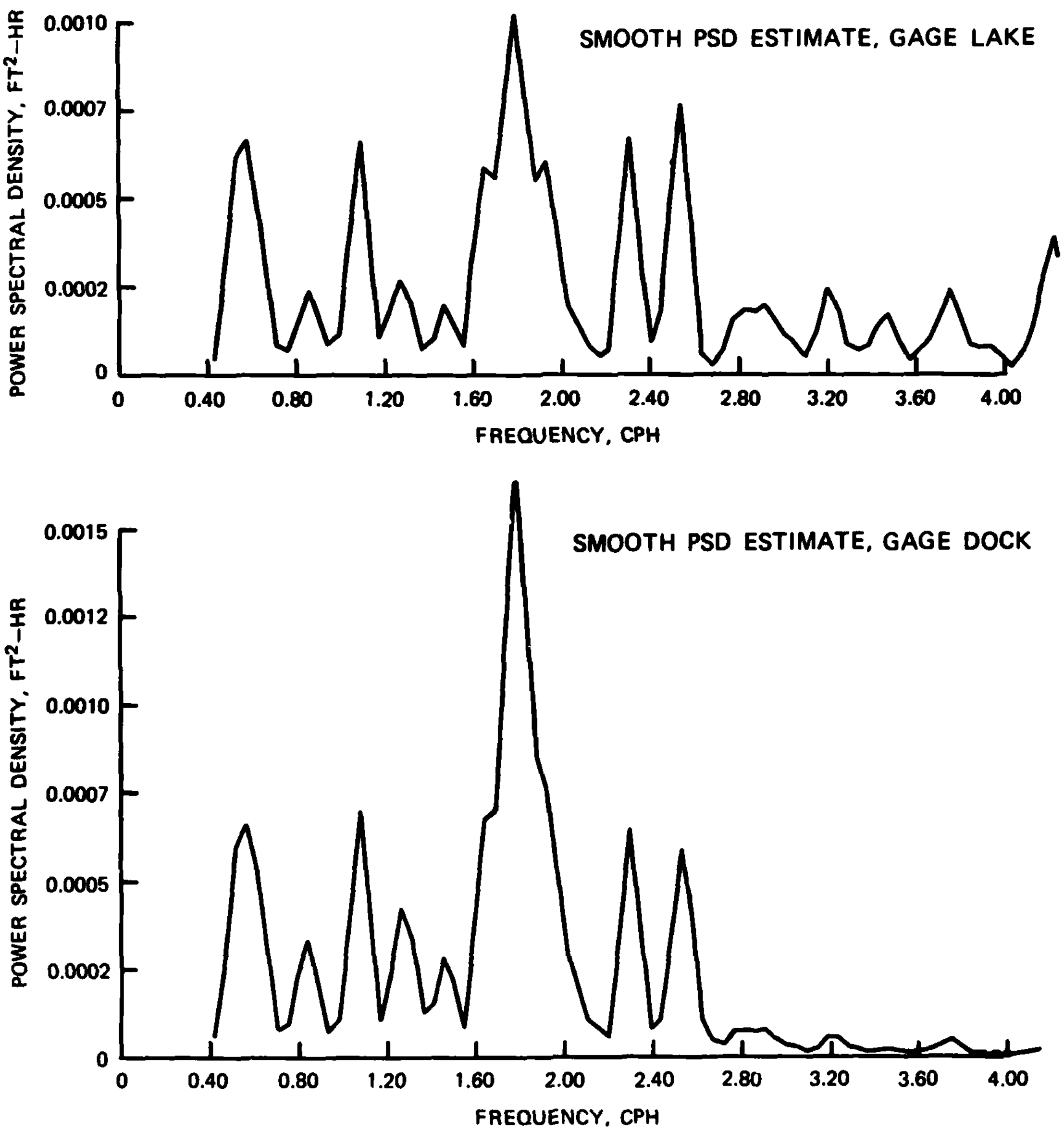


Figure 13. Power spectral density plot, 15 June 1979

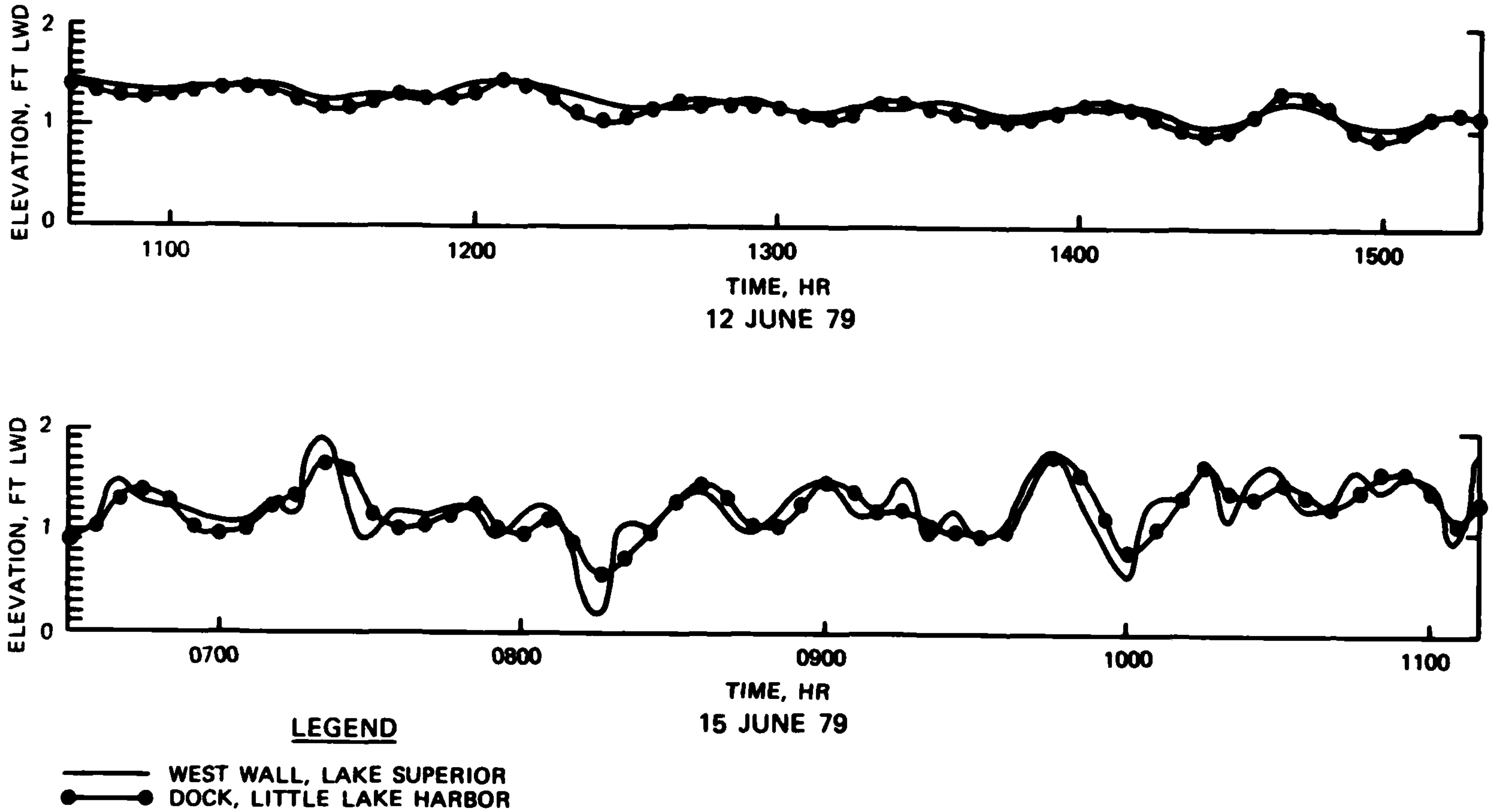


Figure 14. Water-surface elevations versus time

but evidently the harbor isn't able to respond as readily to the resonant periods due to the wide range of frequencies present (Figure 13).

20. The 15 June 1979 water-level variations (Figure 14) indicate that there are significant water-level variations in the harbor over short periods of time, and as a result, significant currents can exist between the lake and the harbor. An analysis of these water-level variations (similar to that used by Seelig and Sorensen (1977)) was performed for the first five data sets in Table 1 to estimate entrance channel current velocities due to the water-level variations. Using the continuity equation between the flow through the entrance channel and the rise of the bay level over a period of time:

$$\bar{V}A_c = A_{bay} \frac{h_{b1} - h_{b2}}{\Delta t}$$

where

$\bar{V}$ = average velocity in the inlet at a cross section of area A_c

A_{bay} = surface area of the bay or harbor

h_{b1} and h_{b2} = the water levels at the start and end of time interval Δt

Δt = time interval

Using $\Delta t = 5$ min (the normal sampling interval for water level), $A_{bay} = 4.2 \times 10^6$ sq ft, and $A_c = 1,325$ sq ft (the area at the minimum cross section of the July 1979 survey), the average estimated velocity was found for each time increment for the first five data sets of Table 1. Figure 15 shows the results from data set 2, with the other results in Plates 10-13. The median estimated velocity for the period shown in Figure 15 is 0.62 fps; however, there are extremes up to 4.5 fps.

21. Further analysis of the water-level data included a determination of seiche period and height by measurement of the time increment between peak values and measurement of peak-to-trough and trough-to-peak distances. This was performed on all available 1979 data for each gage and the results are presented in Table 3. Frequency of occurrence for both seiche height and period was determined from these data and is

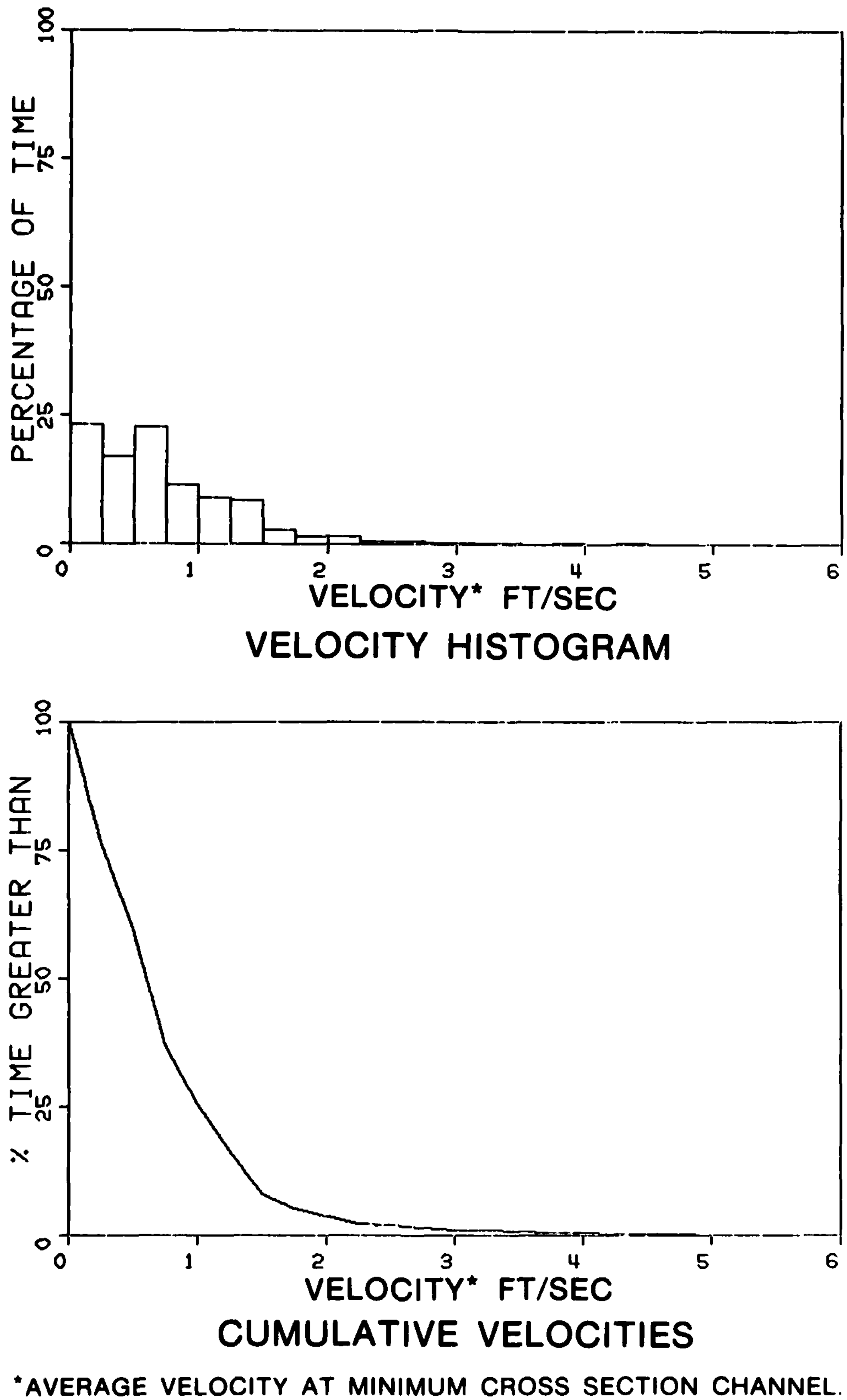


Figure 15. Seiche-generated velocity magnitudes in the entrance channel, 12 June-5 August 1979, data set 2

shown in Plates 14 and 15. Results indicate that the range of seiche heights is usually greater at the harbor dock than in Lake Superior. The effective period measured in the harbor is longer than that of the lake due to the smoothing of water-level oscillations in the harbor (Figure 14). From Plate 14, the median seiche height in Lake Superior near Little Lake is about 0.11 ft and that in the harbor is 0.14 ft. The median period of seiche oscillation (Plate 15) in Lake Superior near Little Lake is 0.46 hr and that in the harbor is 0.54 hr. Based on these data, it was decided that a monochromatic seiche of 0.50-hr period (2-cph frequency) would be reproduced in the model with a range of 0.2 ft. The 0.2-ft range was selected in order to produce significant velocities in the entrance channel. Later in the testing program, a more extreme seiche range of 0.6 ft was used.

Wind-Wave Parameters

22. Winds blowing over the water surface generate wind waves that are the dominant forcing function influencing nearshore processes at Little Lake Harbor. A careful examination was made of prototype information to ensure that the model accurately reproduced wind waves influencing coastal processes in the area.

23. Plate 16 shows a wind rose based on ship observations in Lake Superior (U. S. Army Engineer District, Detroit, 1977). With respect to the orientation of the shoreline at Little Lake (generally east-northeast to west-southwest), predominant winds in duration and magnitude are from the northwest. A wave rose developed from these data also is shown in Plate 16. Another source of wave information was taken from Resio and Vincent (1978). Estimates of extreme wave heights for Little Lake Harbor are shown in Table 4 and corresponding periods are shown in Table 5. The angle classes shown in these tables are 60-deg sectors, with angle class 1 representing the 60-deg sector on the right-hand side of an observer on land looking lakeward, and the other angle classes rotating counterclockwise from angle class 1. Sectors were split and two wave directions selected for each sector. A wave refraction diagram

was computed for each direction for 5-, 7-, 9-, and 11-sec periods using a computer wave-refraction routine. The deepwater wave directions selected were 46.5, 30, 0, 330, 301, and 272 deg. Refraction diagrams then were used to determine the angle of the wave generator at the -66 ft contour (depth of the wave generator pit) to accurately represent the selected deepwater direction. Plates 17-39 show the refraction diagrams. The model wave angles (at the -66 ft contour) selected from the refraction study were 40, 27, 359, 330, 304, and 278 deg. Values in Table 4 were used as the upper bound of wave heights and various smaller heights were selected for testing to cover a variety of conditions. The test waves selected are shown in the tabulation below.

Deepwater Wave Direction, deg	Shallow-Water Wave Test Direction, deg	Period sec	Height ft
46.5	40	5	4
		7	10
		9	16
30	27	5	4, 7
		7	5, 10
		9	8, 16
0	359	5	4, 7
		7	12
		9	10, 21
330	330	5	4, 7
		7	6, 12
		9	10, 21
301	304	5	4, 7
		7	5, 10
		9	8, 17
272	278	5	4, 7
		7	5, 10
		9	8, 17

Simulation of Prototype Sediment

24. The primary problem at Little Lake Harbor is shoaling of the entrance channel, making accurate reproduction of sediment movement and subsequent shoaling in the model of paramount importance. Prototype

sediment is normally fine sand with some cobbles along the shoreline. The Detroit District gathered 118 samples along a number of lines perpendicular to shore in the vicinity of the harbor. The mean diameter of all these samples was 2.21ϕ (0.22 mm) and the standard deviation was 0.42ϕ (0.16 mm < d < 0.29 mm). Maximum and minimum mean values for individual samples were 1.61ϕ (0.32 mm) and 2.78ϕ (0.15 mm).

25. Scaling relations of Noda (1971) were used in selecting a material to model sediment movement. Previous WES studies have successfully used this criterion (Bottin and Chatham 1975) which relates model to prototype ratios of sediment size, sediment specific gravity in water, and horizontal and vertical scales. A graphical solution of the equations is shown in Figure 16 with the associated relationship shown in the lower right-hand corner. This method presumes a distorted-scale model. However, since an undistorted-scale model had been selected to allow accurate reproduction of wave refraction and diffraction simultaneously, a range of sediment scales was determined by first substituting the 1:75-scale ratio for the horizontal scale and determining a sediment size scale for a given specific gravity, and then substituting the 1:75-scale ratio for the vertical scale and determining a sediment size scale ratio for the same specific gravity. Since crushed coal had previously been used successfully in studies similar to Little Lake, a specific gravity of 1.35 (representing coal) was used to determine a range of sediment size ratios (varied from 1.67 to 2.17). Based on a prototype sand size range of 0.15 to 0.32 mm, crushed coal with a size range in the vicinity of 0.25 to 0.69 mm was desired. An existing supply of coal with a medium diameter of 0.50 mm and a distribution as shown in Plate 40 was selected as the model sediment.

Construction of Model Structures

26. The existing structural configuration at Little Lake (Figure 1) was constructed in the model to the specification given for prototype construction (Plate 1). The only variation from scale was the size of stone used in the rubble-mound portion of the breakwater.

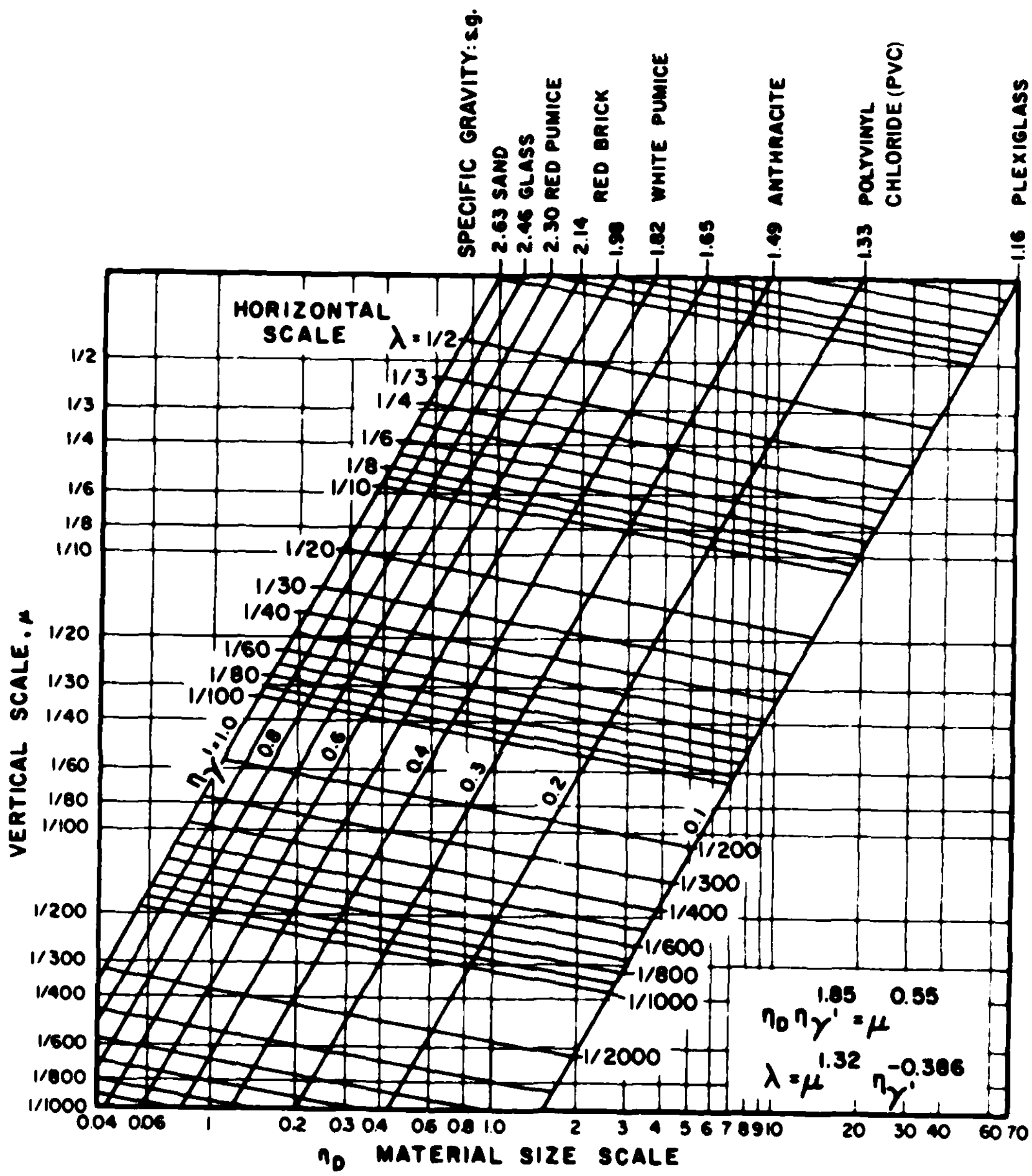


Figure 16. Graphical representation of model law (Noda 1971)

Previous laboratory testing (Dai and Jackson 1966, and Ball and Brasfeild 1967) has indicated that for a 1:75-scale model, stone 1.5 times the scaled size should be used in order to correctly model wave-reflection and transmission characteristics of the rubble-mound structure.

PART IV: TESTING

The Testing Program

27. Testing performed for the model study primarily involved tracer tests, in which sediment tracer material (crushed coal as described previously) was injected into the surf and nearshore zones in the vicinity of the harbor for a given wave condition. Each test was run for a sufficient length of time to allow tracer movement and deposition patterns to develop, and then a photograph was taken to illustrate test results. Also for given wave conditions, a pattern of movement of the water mass in the nearshore zone adjacent to the harbor was determined using dye. Point velocities at selected locations were measured by timing the movement of a patch of dye over a known distance and wave heights were measured at selected locations for various wave conditions. For some tracer tests, seiche oscillations were reproduced in addition to the wave field. Also, seiche oscillations were reproduced and velocity measurements were made with current meters in the entrance channel region. Surface current photographs also were obtained during seiche reproduction by making a 4-sec time exposure of the water surface covered with Styrofoam floats.

28. The testing program followed this sequence: base tests, using existing 1979 conditions with the channel dredged to -10 ft; initial plan testing, in which five proposed plans were examined; additional plan testing, in which plans were refined based on what was learned from the initial plan testing; and final plan testing, where the final plan was examined comprehensively for additional test conditions.

Base Tests of Existing Conditions

29. In order to provide a base for comparison of improvement plan results with existing conditions, a series of base tests were undertaken using the conditions shown in Figure 17. These tests also were used to determine if known shoaling patterns were reproducible in the model. A

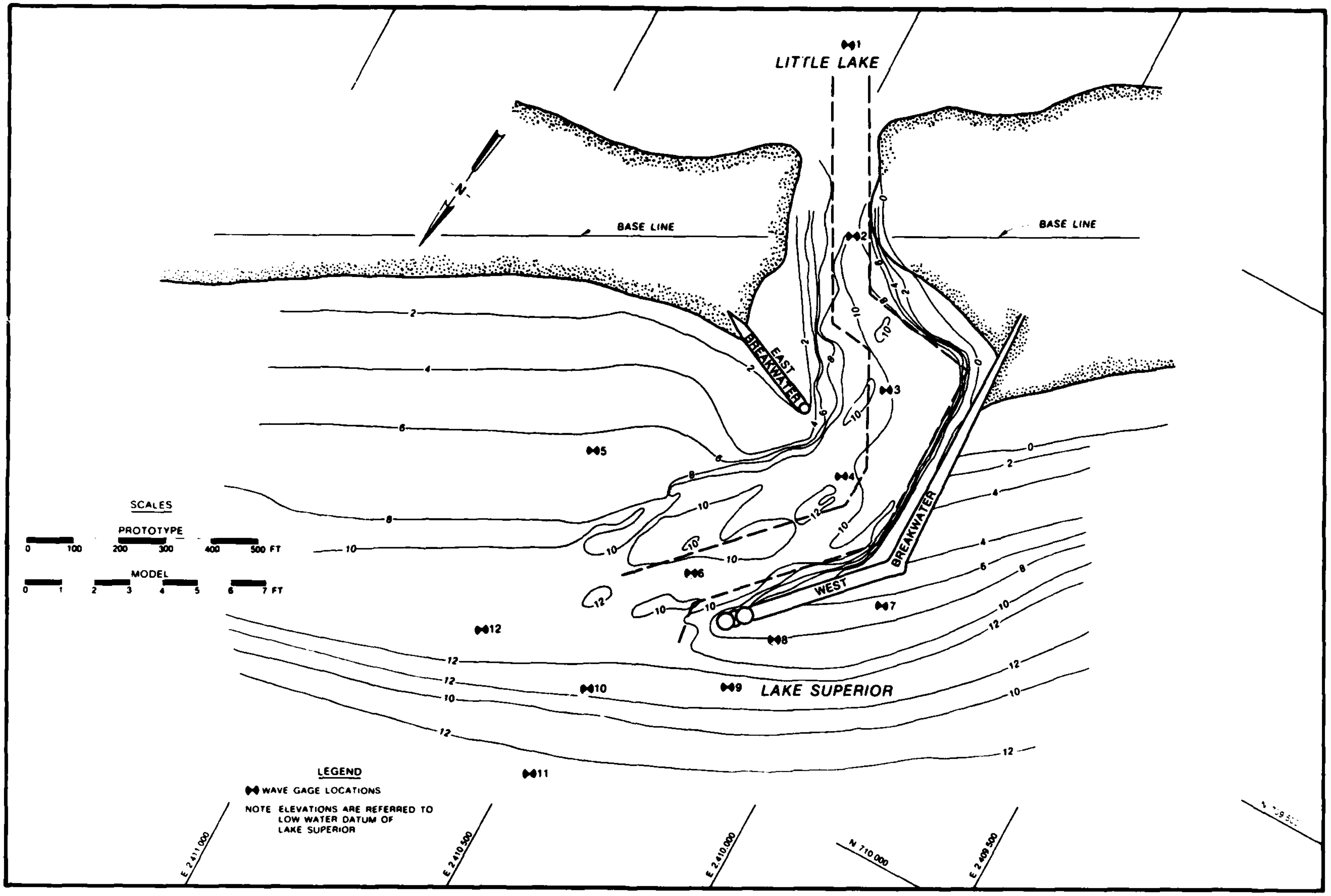


Figure 17. Base conditions

wide variety of test conditions were reproduced during base tests, with six different wave directions and a broad range of wave heights and periods. It was reasoned that if similar trends could be discerned for several tests, then the total number of tests for improvement plans could be reduced to those with varying results. This would result in substantial time and cost savings where a number of plans must be tested. Table 6 outlines the complete tracer testing program and indicates that 52 base tracer tests were completed.

Initial shoaling Tests 1-11

30. Tests 1-11 were run in order to develop testing techniques such as the location of tracer feeding, rate of feeding, and duration of test. The first four tests involved reproduction of the inner bar with coal tracer on both the west and east sides of the harbor for waves from the 278-deg wave direction. Test wave conditions are given in prototype periods and heights, and velocities also are presented in prototype units of measurement. Test duration, when mentioned or noted on photographs, is given in model hours. Test 1 (Plate 41), run with a 7-sec, 6.5-ft wave, showed tracer movement along the west breakwater toward the channel. Some tracer migrated across the channel and joined with tracer east of the east breakwater where it moved into the eastern edge of the channel, a pattern similar to that followed by current flow described by Saylor (1966).

31. Test 2 (Plate 42) had similar wave conditions as Test 1 but the tracer was placed outside the breaker zone on the west side of the harbor. Strong tracer movement past the harbor was noted. Paths of sediment transport paralleling the outer leg of the west breakwater were due to the incident-reflected wave interaction lakeward of this breakwater. Tracer movement through the west breakwater also was noted.

32. Test 3 (Plate 43) was run with a 4.5-ft, 7-sec wave (selected because it broke at the base of the outer leg of the west breakwater). Tracer moved along the breakwater and deposited across the channel entrance, a shoaling pattern which occasionally occurs in the prototype (see Figure 3b). Movement along the east breakwater toward the channel was negligible for this smaller wave condition. Test 4 (Plate 44) was a

repeat of Test 3 with a 0.2-ft seiche reproduced. Results are fairly similar to Test 3 except that the shoal at the tip of the west breakwater was more rounded in the channelward direction due to the currents, and there was a small movement of tracer along the east shore and breakwater into the channel due to the inflow of seiche currents along this structure.

33. Test 5 (Plate 45) initiated a series of tests for which coal was introduced into the model about 1,500 ft east of the study area. The tracer accumulated at the base of the east breakwater and gradually leaked off into the channel. Test 6 (Plate 46), with a 7-sec, 10-ft wave from a 330-deg azimuth, was a continuation of Test 5 in that the tracer was not removed after Test 5. Although the 330-deg angle produced easterly drift on a straight segment of beach, refraction and diffraction in the vicinity of the harbor caused a local reversal of longshore currents and caused tracer migration into the channel along the east breakwater.

34. Test 7 (Plate 47) and Test 8 (Plate 48) were run with the same wave conditions but Test 7 included reproduction of the 0.2-ft, 30-min-period seiche. Tracer in each test moved into the edge of the channel from alongside the east breakwater as has occurred in the prototype (Figures 3a and 3b). Seiche-generated currents tended to distribute the tracer farther along the channel axis than when absent. Each test was run for 2 hr (model time).

35. Test 9 (Plate 49) was a dye test in which dye was injected into the surf zone east of the structures. There was a split of the longshore current as it approached the east breakwater with a portion of the current continuing toward the east breakwater and the other portion moving lakeward toward the tip of the west breakwater. Test 10 (Plate 50) was a duplicate of Test 8 conditions except that tracer was fed over a line extending farther lakeward than that of Test 8. A larger accumulation along the east breakwater and strong movement into the channel were noted. Test 11 (Plate 51) was cut to 0.5 hr (model time) due to operational problems so that development of tracer movement

was only beginning to start with minor traces of sediment accumulating along the east breakwater.

Base Tests 12-47

36. Base Tests 12-47 (Plates 52-123) contained six sets of tests, each set for a different wave angle and containing six tests representing a variety of wave periods and heights. A plate depicting current patterns and velocities follows each shoaling test plate.

37. Plates 52-63 (Tests 12-17) show test results for the 330-deg wave direction. These waves have a near normal approach to shore as can be seen from the refracted wave crests in Plates 22, 28, 34, and 39. The 7-sec waves transported the most tracer toward the channel along the east breakwater since these waves produced the best-developed longshore current system on the east shoreline. The 5- and 9-sec waves tended to develop easterly flowing circulation cells along the east shoreline, limiting the amount of sediment that could be carried toward the channel. Longshore currents up to 2.9 fps were measured along the lakeward face of the east breakwater and up to 4.3 fps along the lakeward face of the west breakwater. Circulation currents in the outer portion of the channel were nearly always directed lakeward.

38. Plates 64-75 (Tests 18-23) present results from the 304-deg wave direction. Tracer was injected both upcoast on the west side and downcoast along the east shoreline. Tracer movement on the east shoreline was always channelward (toward the west) on the lee of the west breakwater, due to the combined refraction and diffraction of the wave. The 5-sec, 4-ft wave did not bring tracer into the channel region. A fillet was developed against each breakwater. The 5-sec, 7-ft wave brought some tracer to the west breakwater tip where it was deposited, but the greater portion of tracer bypassed the harbor on the outer bar as shown in Plate 66. The 7-sec, 5-ft wave (Plate 68) was similar to the previous wave except that more tracer moved along the outer leg of the west breakwater and deposited in the outer portion of the entrance channel. The 7-sec, 10-ft wave tended to move the tracer straight across the entrance (Plate 70). The 9-sec, 8-ft wave showed heavy tracer movement in all offshore areas (Plate 72), as did the 9-sec,

17-ft wave (Plate 74). There was also tracer movement over and through the inner leg of the west breakwater, a situation observed in the prototype. The strongest longshore currents (up to 4.3 fps) existed along the lakeward face of the outer leg of the west breakwater. Circulation patterns were very similar for each wave condition, with the usual eddy circulation in the lee of the west breakwater.

39. Tests 24-29 (Plates 76-87) show results for the 278-deg wave direction, the sharpest approach angle tested from the west side of the harbor. The 5-sec, 4-ft wave (Plate 76) produced tracer movement along the lakeside of the west breakwater with accretion at the tip of the structure. A fillet developed upcoast from the west breakwater. Test results for the larger waves were very similar to those for the 304-deg direction except slightly greater rates of movement were noted due to the sharper wave angle and higher alongshore velocities. Circulation patterns were similar to those for the 304-deg wave direction.

40. Tests 30-35 (Plates 88-99) were performed with a 27-deg wave angle. The 5-sec, 4-ft and 5-sec, 7-ft waves both brought significant amounts of tracer into the channel (Plates 88 and 90), with some tracer bypassing westward for the 7-ft wave. The 7-sec waves (Plates 92 and 94) brought smaller amounts of tracer to the entrance channel and bypassed significant amounts due to their more lakeward breaker location. The 9-sec waves (Plates 96 and 98) bypassed significant amounts of sediment, but also shoaled the eastern side of the channel.

41. Tests 36-41 (Plates 100-111) were conducted using the 40-deg wave direction, the sharpest angle from the east side of the harbor. Channel shoaling was most significant for the 5-sec, 7-ft wave (Plate 102). All tests moved tracer around the east breakwater to the channel edge. The 7-sec, 10-ft wave had the least channel shoaling due to a reversal of circulation patterns near the east breakwater as a result of the westward alongshore current diverting lakeward before reaching the east breakwater. Generally, patterns of sediment deposition were similar for the 27- and 40-deg wave approaches. Minor variations were mostly due to the appearance of the current reversal at the base of the east breakwater.

42. Tests 42-47 (Plates 112-123) illustrate tracer movement for the 359-deg wave direction. Channel shoaling was much less than for less normal wave approaches.

Seiche tests with tracers

43. After testing the six Base Test wave directions, three wave conditions (two from the northeast and one from the northwest) were selected for testing with seiching reproduced. The three selected conditions were the 304-deg, 7-sec, 10-ft wave; the 270-deg, 7-sec, 10-ft wave; and a 27-deg, 5-sec, 4-ft wave. First a 0.2-ft, 30-min-period seiche was run continually for the first two above-mentioned wave conditions. Then a 0.6-ft, 30-min-period seiche was run for all three wave conditions. Results are shown in Plates 124-128.

44. Plates 70, 124, and 126 show a nonseiche condition, the 0.2-ft seiche, and the 0.6-ft seiche for the same wave condition. The first two tests were fairly similar as far as deposition into the channel near the east breakwater. The 0.6-ft seiche (Plate 126) showed increased deposition in the channel as the seiche-generated velocities aided in bringing tracer into the channel for the 304-deg wave condition.

45. Plates 94, 125, and 127 can be compared for the 27-deg, 7-sec, 10-ft wave condition. The nonseiche and 0.2-ft seiche test results were similar with the 0.6-ft seiche test showing a slight increase in shoaling and more movement of tracer toward the channel throat between the breakwaters.

46. Plate 128 (seiche) can be compared with Plate 88 (nonseiche) to show that deposition patterns are similar but that there was an increased amount of deposition in the vicinity of the east breakwater tip for the seiche condition.

47. Results of the seiche tests indicated that seiching did not seem to produce appreciably different sedimentation patterns than nonseiche wave-only tests, but did slightly increase the rate of sedimentation and brought tracer farther into the channel (in a shoreward direction).

48. After an examination of all Base Test data, it was determined that the 304- and 27-deg wave directions were representative of the

shoaling patterns observed with other wave directions. Therefore, to reduce the number of tests required, only these directions were used for initial tests of the various improvement plans.

Initial Testing of Plans

49. Five basic plans were initially developed for testing and are shown in Plates 3-7. Plans 1, 2, 3, and 4 were similar to Alternatives 2, 3, 4, and 5 of Detroit District tests (U. S. Army Engineer District, Detroit, 1977). Alternative 1 of Detroit District tests was a groin system and was not selected for testing. Plan 5 was similar in orientation to Alternative 6 of these tests except that report called for sand-filled barges to create the breakwater in the orientation of Plan 5 rather than with the use of a rubble-mound structure. Plans 1A and 1B (Figures 18 and 19) were added as shortened versions of Plan 1. From this point on, shoaling test numbers appearing in plates will not follow consecutively because results have been organized in order of plan number.

Plan 1

50. The 900-ft addition to the east breakwater appeared to have created a sediment trap inside the jetties for material from the east that might move around its tip. Plates 129-132 show shoaling in the entrance for the 5-sec, 7-ft and 7-sec, 10-ft waves from the 27-deg direction. Comparison with Base Test results (Plates 90 and 94) indicates increased shoaling in the channel for each condition with Plan 1. Strong velocities were noted on the east side of the 900-ft addition (Plates 130 and 132). Plates 133-138 show results for the 304-deg wave approach. While most tracer bypassed the entrance for the 5-sec, 7-ft and 7-sec, 10-ft waves, there were small accumulations near the tip of the west breakwater that were not present for the Base Tests (Plates 66 and 70). The 9-sec, 8-ft wave (Plate 137) had the most severe channel shoaling as was the case for the Base Test (Plate 72).

Plan 1A

51. Halving the Plan 1 extension of the east breakwater produced

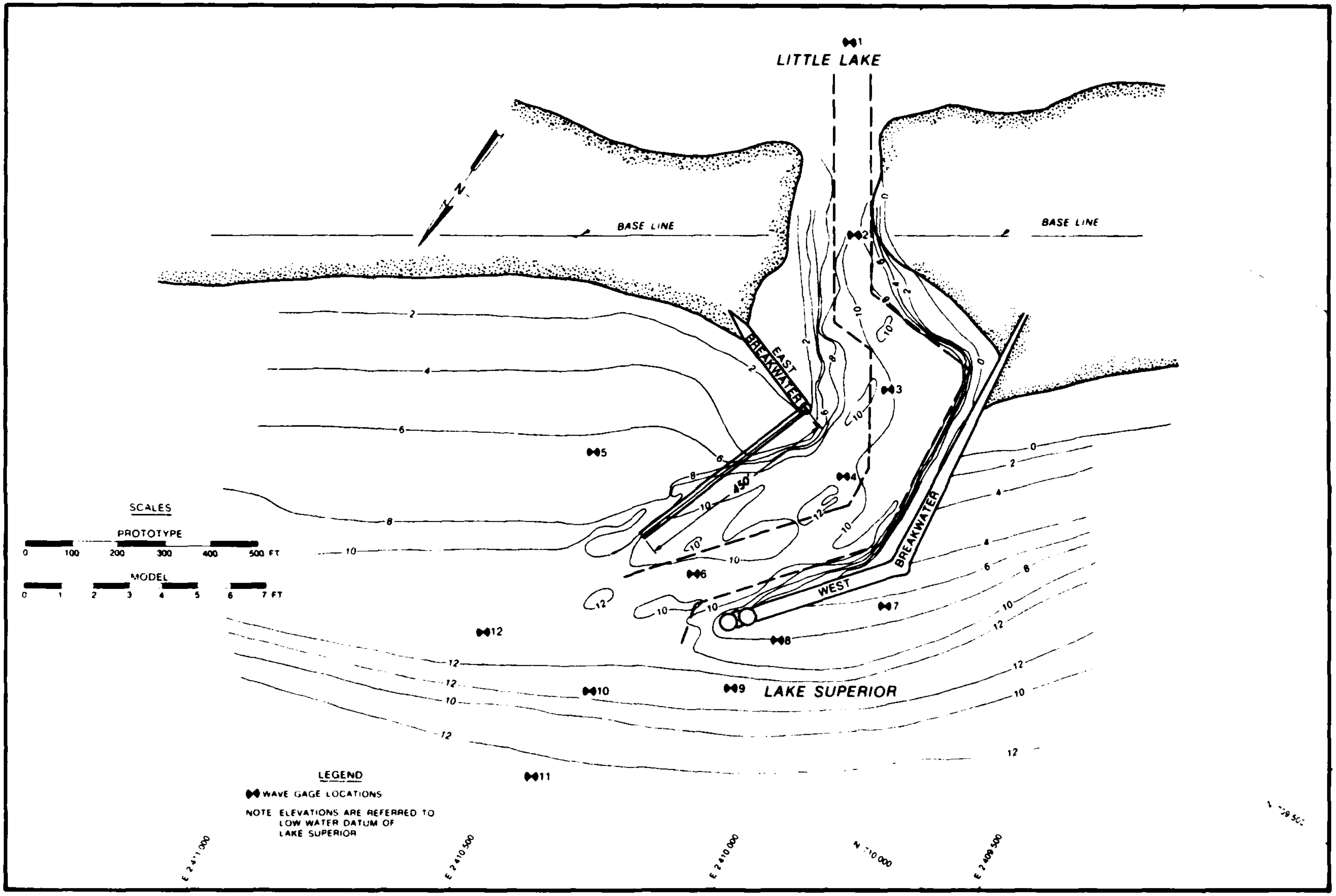


Figure 18. Plan 1A

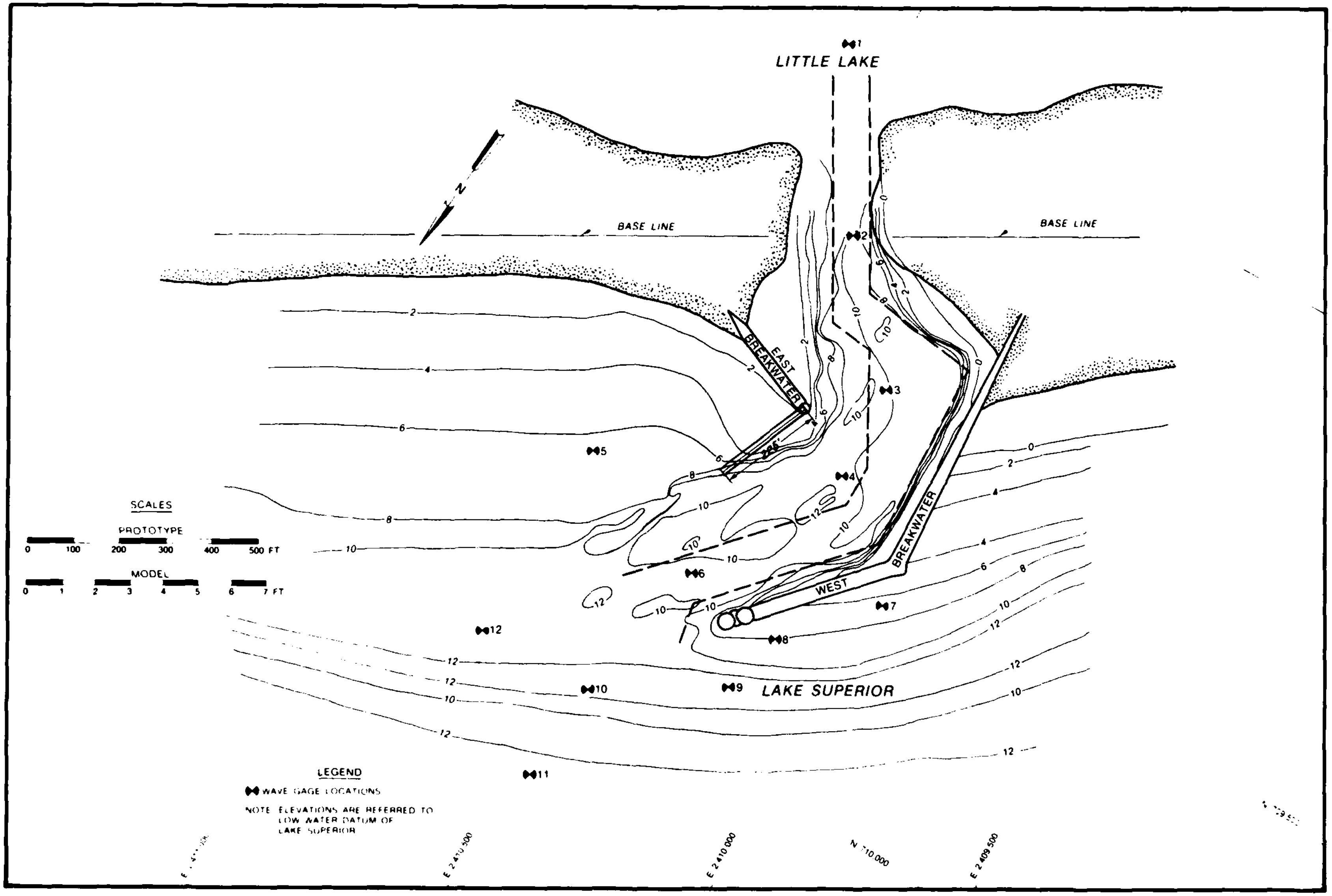


Figure 19. Plan 1B

a 450-ft extension of the east breakwater and test results are shown in Plates 139-148. Shoaling in the entrance channel for waves from the 27-deg direction (Plates 139 and 141) was reduced from base conditions (Plate 90) for the 5-sec, 7-ft wave and increased over base conditions (Plate 94) for the 7-ft, 10-sec wave. The 304-deg waves produced only minor changes for the 5-sec, 7-ft wave and 7-sec, 10-ft wave when compared with the base (compare Plates 66 and 70 with 143 and 145). Results for the 9-sec, 8-ft wave were similar from plan to base (Plates 147 and 72) except that tracer moved slightly deeper into the outer part of the channel.

Plan 1B

52. Halving the Plan 1A addition to the east breakwater produced the 225-ft spur of Plan 1B. Tests for the 27-deg, 5-sec, 7-ft and 7-sec, 10-ft waves (Plates 149-152) showed less shoaling in the channel than for Base Tests (Plates 90 and 94). Results for the 304-deg wave direction (Plates 153-158) showed similar patterns of shoaling when compared with the Base Tests (Plates 66, 70, and 72) except for the 9-sec, 8-ft wave which had shoaling patterns encroaching farther bayward along the channel during the plan test.

Plan 2

53. Plan 2 (a 700-ft extension perpendicular to the east breakwater with a 250-ft angled extension paralleling the shoreward contours) test results are presented in Plates 159-168. The 5-sec, 7-ft wave from 27 deg (Plate 159) produced heavy shoaling in the channel with minor shoaling for the 7-sec, 10-ft wave (Plate 161). In each case, a greater amount of shoaling occurred than for base conditions (Plates 90 and 94). With 304-deg waves, the 9-sec, 8-ft wave produced the greatest amount of shoaling (Plate 167), but the amount was less than that for the Base Test. For the 7-sec, 10-ft and 5-sec, 7-ft waves, most of the tracer that was not trapped in the fillet bypassed the entrance channel.

Plan 3

54. This plan was similar to Plan 2 except that a 225-ft extension (angled northward) was added to the west breakwater. Results are shown in Plates 169-178. The 5-sec, 7-ft wave from 27 deg (Plate 169)

was not able to move tracer sediment effectively past the entrance due to the extension, and shoaling was greater than the base condition (Plate 90). The 7-sec, 10-ft wave from 27 deg (Plate 171) did move most tracer past the channel entrance toward the west. All three waves from the 304-deg direction produced heavy shoaling in the entrance (Plates 173, 175, and 177), greater than that of base conditions (Plates 66, 70, and 72). This was due to the eddy-like circulation in the lee of the west breakwater extension (see Plates 174, 176, and 178).

Plan 4

55. Plan 4 added the 600-ft-long offshore breakwater to the Plan 3 configuration. Results of tracer and circulation tests are shown in Plates 179-188. Shoaling in the channel was minor for the 27-deg wave angle (Plates 179 and 181) as strong currents moved through the gap between the shore-connected breakwater tip and the offshore breakwater (Plates 180 and 182). Shoaling for the base 5-sec, 7-ft condition was much greater in comparison (Plate 90). Movement of tracer with waves from 304 deg created heavy shoaling in the west channel entrance, especially for the 7-sec, 10-ft and 9-sec, 8-ft waves, greater than that of base conditions (Plates 66, 70, and 72). There was strong sediment tracer movement on the lakeward side of the offshore breakwater due to the incident-reflected wave field plus strong currents.

Plan 5

56. Plan 5 added an 875-ft shore-connected east breakwater to the base condition making approximately a 50-deg angle with the shoreline and directed to the outer tip of the west breakwater. Plan 5 test results (without seiche action) are shown in Plates 189-198. Each 27-deg wave introduced tracer shoaling into the entrance (Plates 189 and 191) although amounts for the 5-sec, 7-ft condition were much greater than those for the 7-sec, 10-ft condition. The amount of shoaling was comparable to that of the base conditions (Plates 90 and 94). Lines of tracer movement are seen as a result of the incident wave-reflected wave interaction, which in addition to the wave-generated currents aids in moving sediment toward the channel entrance. When waves from the 304-deg direction were reproduced, only the 9-sec, 8-ft wave caused significant

shoaling at the entrance channel (Plate 197) though slightly less than the Base Test (Plate 72). Plates 199 and 200 show results of reproducing a 0.6-ft, 0.5-hr-period seiche with the 5-sec, 7-ft, 27-deg wave and 9-sec, 8-ft, 304-deg wave, respectively. When each of these tests is compared with the nonseiche tests (Plates 189 and 197) it is seen that shoaling patterns were similar in location but extended bayward along the channel (i.e., there was further penetration of tracer due to the seiche-generated currents in the channel).

Wave-height testing, Plans 1-5

57. Wave gages were located in the positions shown in Plates 3-7 and two wave directions were tested (27 and 304 deg) with the water level at +1.0 LWD. Gage locations were identical for all wave tests. Results for the various wave periods and heights are shown in Tables 7 and 8. For the 27-deg wave approach, gages 1-5 generally show reductions from the Base Test waves for all plans. Gage 6, at the existing channel entrance, had some increases in wave height over the base condition for Plans 1, 2, and 5, with Plans 3 and 4 showing almost all reductions in height. Gages 7-12 showed expected variations for the given wave angle with respect to the structural alterations.

58. The 304-deg wave approach for gages 1-5 showed some small increases over base for what were initially relatively small wave heights. Plans 1 and 2 indicated slight increases at gage 4 apparently due to waves reflecting off the extended east breakwater. This effect was also noticeable at gage 6 for some conditions for Plans 1 and 2.

59. At the conclusion of this initial test series, an evaluation of Plans 1-5 was made. It was noted, usually, that when the east and west breakwaters were extended to unequal distances offshore, eddy zones were created which trapped sediment, as shown in Plans 3 and 4. Plan 5 provided an easy route for sediment from the east to enter the channel. Plan 2 also seemed to catch sediments from the east once it moved around the long extension of the east breakwater. Plan 1 responded in a similar way to waves from the 27-deg direction as did Plan 2. Plan 1 also provided a reflecting surface off the extension to the west breakwater for waves from the 304-deg direction to make turbulent entrance

conditions. Plan 1A shoaled moderately with waves from the 27-deg direction. However, Plan 1A maintained the existing circulation along the east shoreline (for waves from the west) as did Plan 1B, which tended to continually maintain movement of sediment to the edge of the channel from the east. The short length of Plan 1B would probably hasten this effect for that case, although the short-term tracer tests did show good results. The extensive total structure length for many of the plans (e.g., Plans 3 and 4) was also an undesirable feature.

Additional Plans

60. Plans 6, 7, and 8 (Figures 20, 21, and 22) were developed with a major emphasis on minimizing structure length.

Plan 6

61. Plan 6, with results shown in Plates 201-210, was a breakwater installed perpendicular to the existing beachline which initiated at the -4 ft contour and extended the same distance lakeward as the west breakwater for a total length of 500 ft. It was anticipated that the gap between this structure and the shore would eventually close with the development of a fillet. Crest elevation of the jetty was +6.0 ft in contrast to the previous +8 ft elevations of Plans 1-5. This would permit some overtopping by larger waves that would set up an outward-directed current through the entrance channel gap (Plates 202 and 204). The 27-deg, 5-sec, 7-ft wave did have an influx of sediment tracer near the west breakwater tip, but there was also good bypassing (Plate 201). Shoaling was similar to the base condition (Plate 90). For this short test duration (2 hr), the shoreward gap was not closed and there was some tracer movement past this gap but with only small amounts penetrating toward the channel. There was more channelward movement via this route for the 27-deg, 7-sec, 10-ft wave (Plate 203), although there was little influx into the channel from the lakeward entrance. With waves from 304 deg, only the 9-sec, 8-ft wave (Plate 209) produced channel shoaling and this was concentrated at the entrance gap.

Plan 7

62. Plan 7 was a variation of Plan 5 except that the proposed

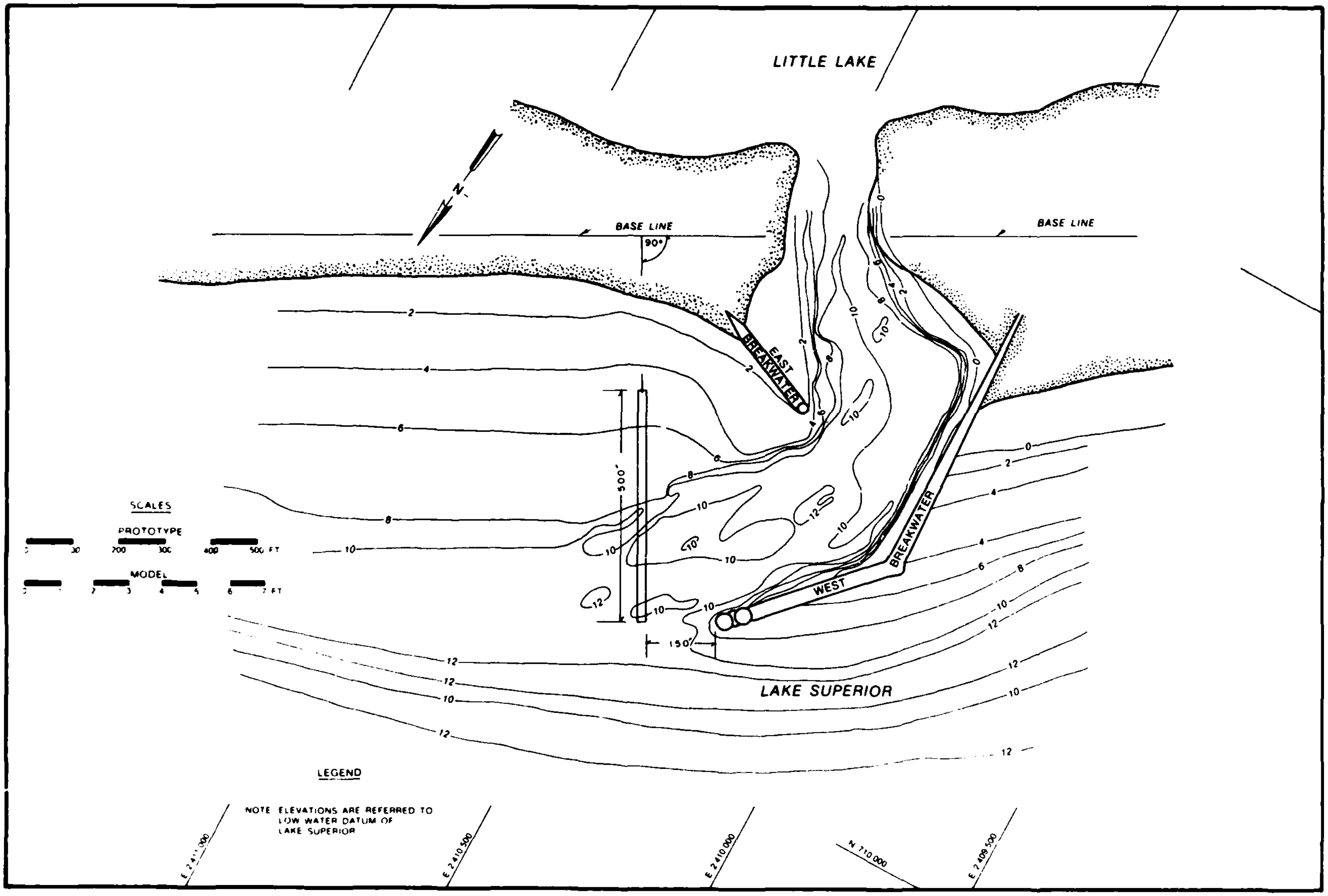


Figure 20. Plan 6

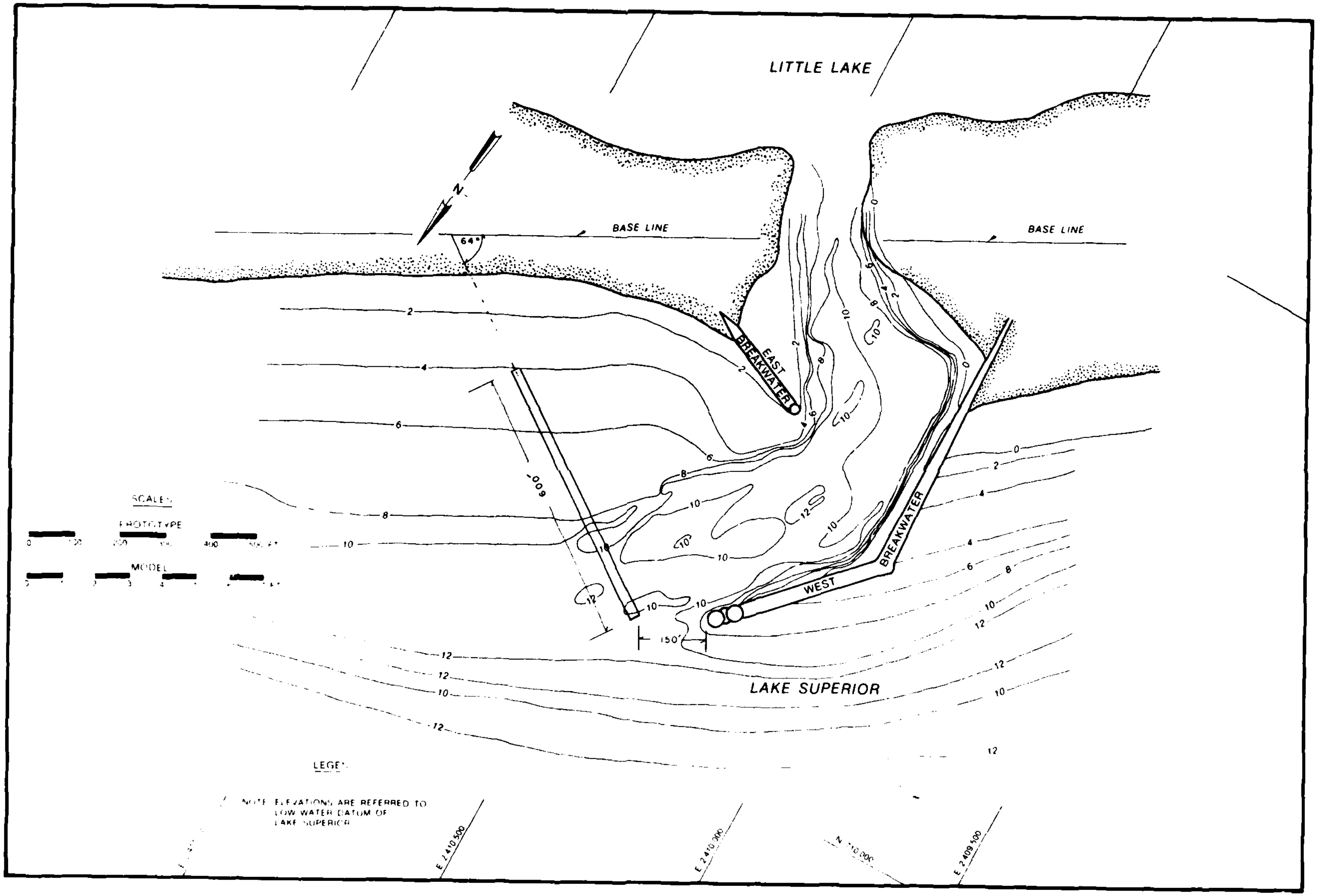


Figure 21. Plan 7

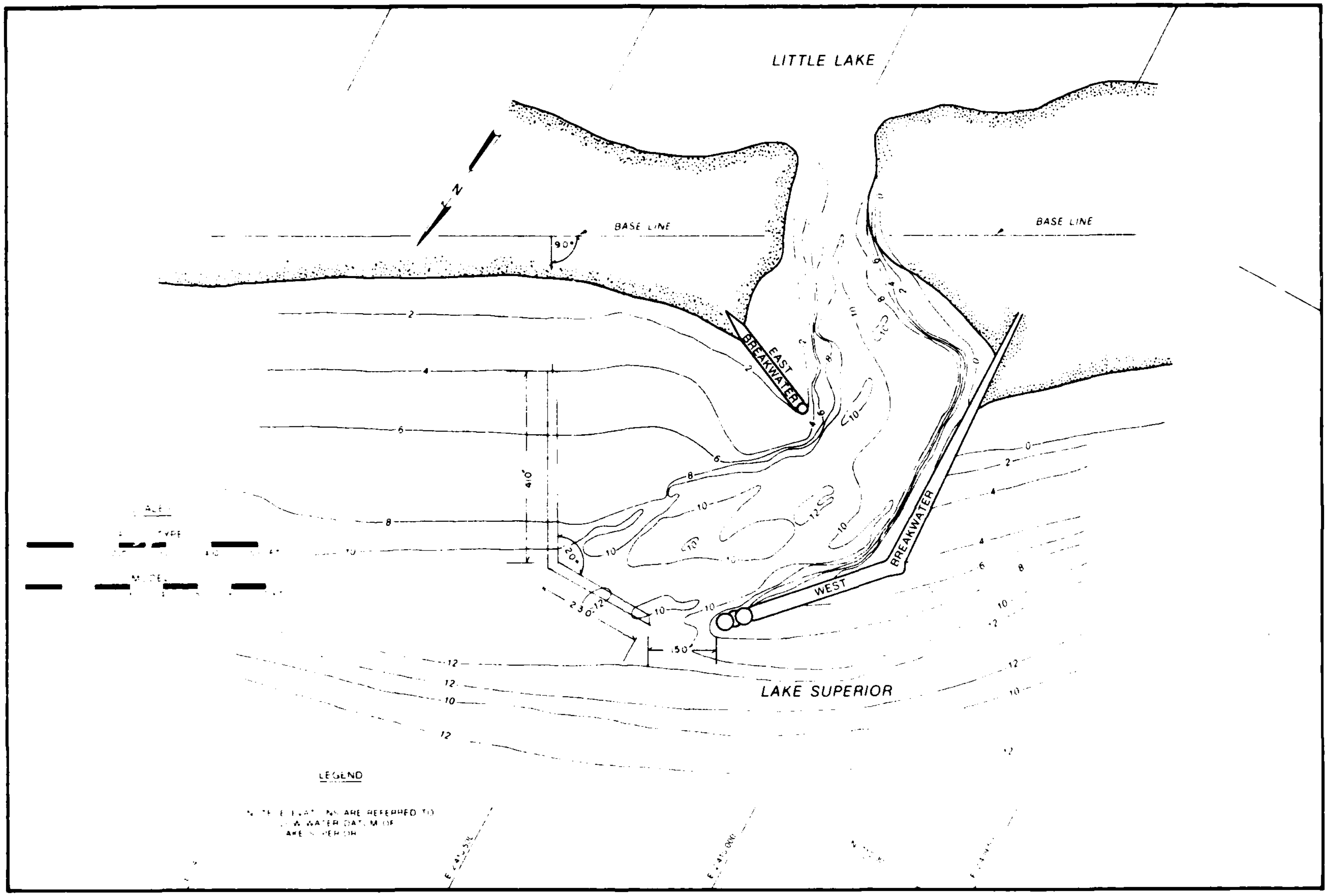


Figure 22. Plan 8

breakwater was shifted about 150 ft eastward, extended to the same depth contour as the west breakwater, and shortened to 600 ft long. Data are presented in Plates 211-216. As a result of the change in entrance location, this provided improved bypassing relative to Plan 5 (and less deposition than the base condition), especially near the entrance since less tracer entered the gap between breakwaters (compare Plates 90, 189, and 211). The other 27-deg wave indicated no channel shoaling (Plate 213). With the 304-deg direction, only the 9-sec, 8-ft wave caused shoaling of the entrance, similar to that of Plan 6 (compare Plates 209 and 216) and less than that of the base condition (Plate 72).

Plan 8

63. The Plan 8 breakwater had a 410-ft-long perpendicular segment and a 230-ft-long dogleg segment as shown in Figure 22. It was anticipated that this might provide better temporary storage for sediments from the east and tend to cause this sediment to be stored far enough away from the harbor entrance that subsequent waves from the west would push those sediments back toward the east (the net wave energy is from the west). Plates 217-226 show Plan 8 test results. The 27-deg, 5-sec, 7-ft wave showed little movement of tracer into the entrance (compare Plate 217 with base, Plate 90) and good bypassing as did the 7-sec, 10-ft wave results shown in Plate 219. With waves from the 304-deg direction, only the 9-sec, 8-ft wave produced entrance channel shoaling and the band of sediment was smaller than that of Plan 6 or 7 or the base condition. (Compare Plates 72, 209, 216, and 225.)

Plan 9

64. This plan (Figure 23) was part of a demonstration test during a planning meeting and varied from Plan 8 only in that the 470-ft-long shoreward leg extended slightly farther lakeward than that of Plan 8 (as a result it had a flatter 200-ft-long outer leg which extended westward toward the entrance). The objective of Tests 105 and 105A was to investigate development of a fillet connecting the landward leg of the new breakwater (which terminated its shoreward end at -4 ft) to shore. With a 5-sec, 4-ft, 27-deg wave reproduced to simulate a long-term average condition, Plate 227 shows fillet development after 2 hr of testing and

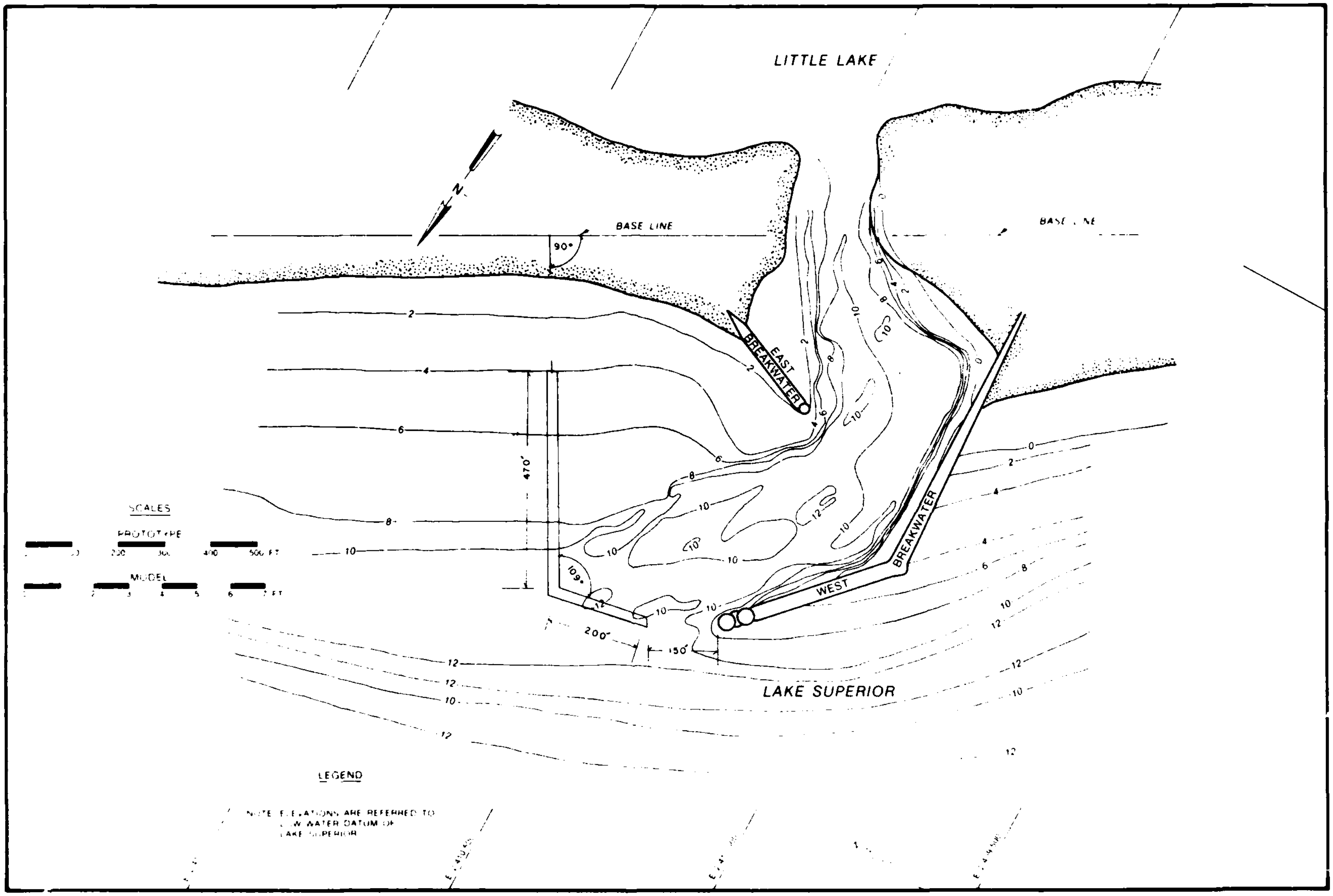


Figure 23. Plan 9

Plate 228 shows the fillet attached to the new east breakwater after 8 hr of testing.

Plan 10

65. This plan (Figure 24) was another adaption of Plan 8 in which the 120-ft-long outer leg of the new east breakwater was shortened and the entire 545-ft-long landward leg of the breakwater was shifted west about 100 ft. Heavy shoaling occurred at the entrance for the 5-sec, 7-ft, 27-deg wave (Plate 229) which indicated that the outer leg was not long enough to provide for satisfactory natural bypassing.

Plan 8A

66. This plan was identical with Plan 8 except that the starting point for the breakwater was moved from the -4 ft contour to the -5 ft contour (this plan was designated Plan 8A, Figure 25), providing a reduction in total length of 70 ft. This did not significantly increase the influx of sediment along the east shoreline toward the existing east breakwater (compare Plate 217 with Plate 230). Plate 231 shows the shoreline region more clearly for a repeat test of this same condition. The lakeward tip of the new east breakwater was shifted slightly lakeward to become exactly even with the existing west breakwater tip and two tests were run, one (Plan 8A) in which the new east breakwater tip was rock (Plate 232) and one (Plan 8B) in which a caisson matching the existing west jetty tip was installed (Plate 233).

Plan 8B

67. Plan 8B is shown in Figure 26, and the test results are shown in Plates 233 and 234. The same 5-sec, 7-ft, 27-deg wave was used for tests of both Plans 8A and 8B, and little difference was noted in shoaling patterns. Therefore, Plan 8B was selected for more detailed final testing since it was believed that a caisson on each side of the entrance channel would provide good visual definition for the location of the entrance channel during rough weather conditions. Plan 8B then was subjected to the usual tests from the 27- and 304-deg wave direction plus additional long-term tests and sensitivity shoaling tests in which waves from 40 and 359 deg were reproduced. These results are shown in Plates 235-250. The 7-sec, 10-ft, 27-deg wave caused no shoaling

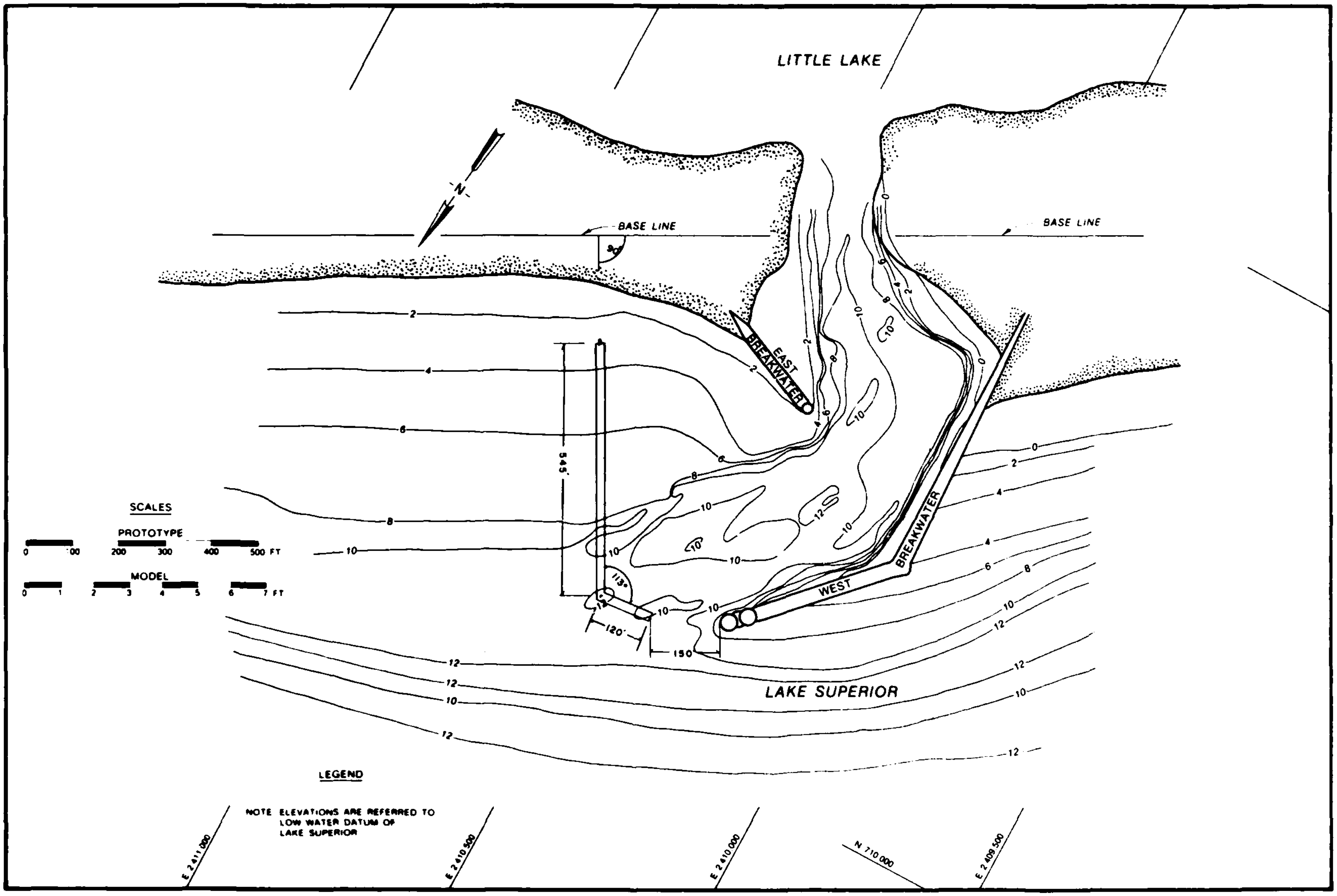


Figure 24. Plan 10

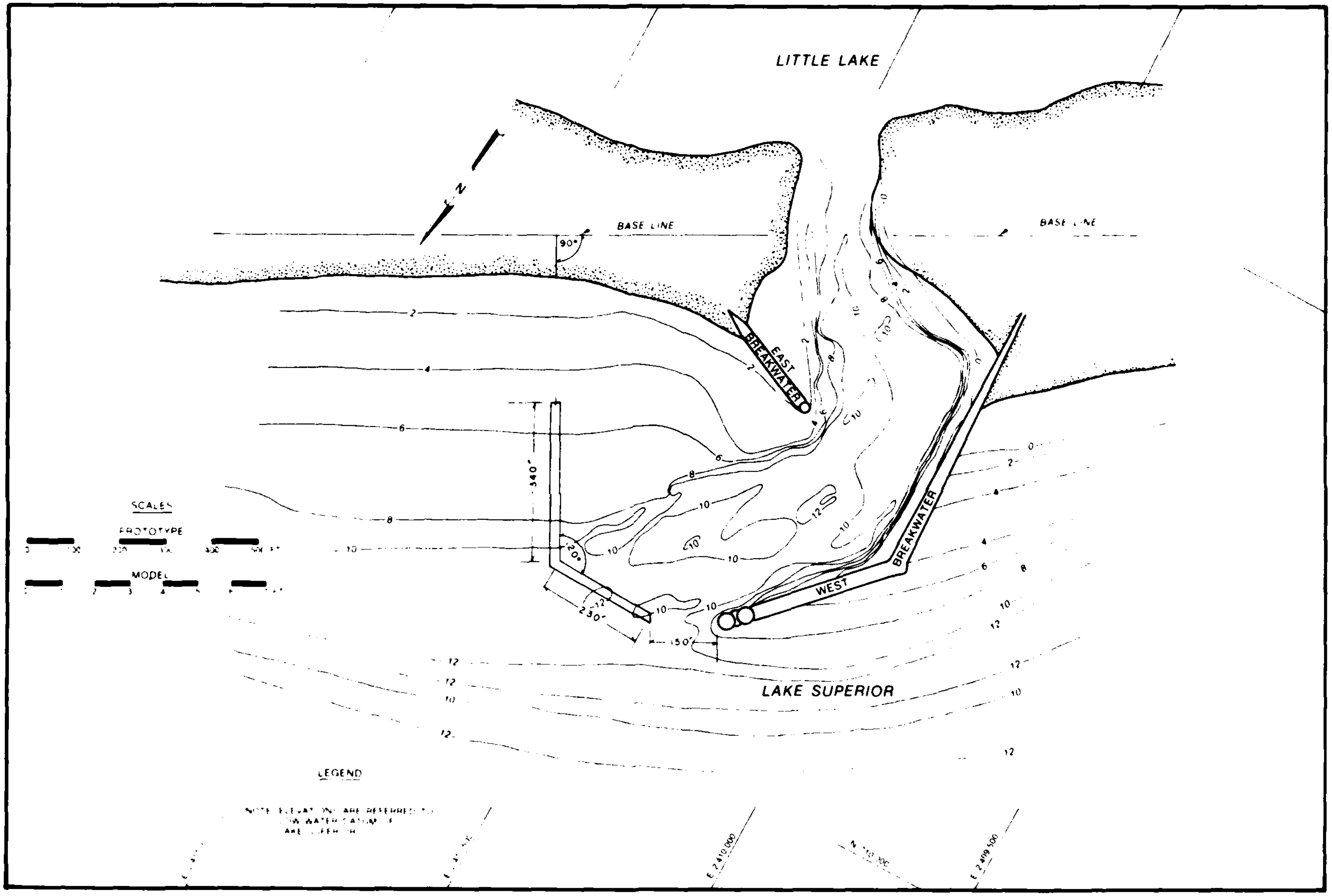


Figure 25. Plan 8A

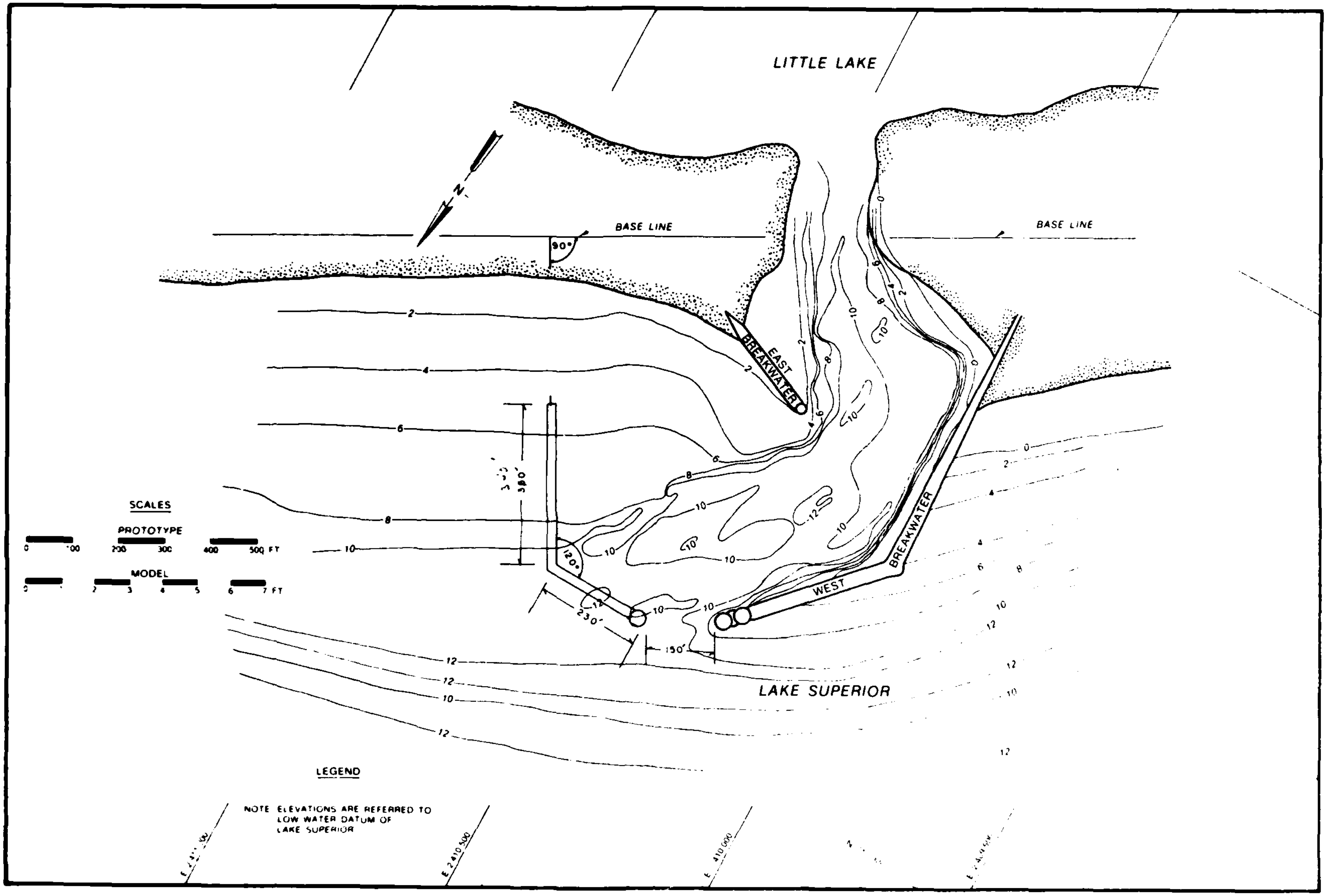


Figure 26. Plan 8B

problems (Plate 235). There was an influx of tracer along the shoreline from the east toward the existing east breakwater, but the movement was stopped by the breakwater, unlike that of the base condition where sediment tracer entered the channel along the existing east breakwater (Plate 94). The 40-deg, 5-sec, 7-ft wave (Plate 237) showed good bypassing and offshore storage of tracer, less channel entrance shoaling than the 27-deg, 5-sec, 7-ft wave, and much reduced channel shoaling when compared with the Base Test (Plate 102). Tracer material completely bypassed the entrance for the 7-sec, 10-ft, 40-deg wave (Plate 239), while the base condition test (Plate 106) had shown some movement into the entrance. No significant tracer movement through the gap between the shoreline and the shoreward end of the new breakwater was observed. No problems were observed for the 359-deg wave approach for the two waves tested (Plates 241 and 243) while the base condition indicated sediment tracer moving toward the channel around the existing east breakwater (Plates 114 and 116). The wave creating the greatest shoaling problems from previous testing, the 9-sec, 8-ft, 304-deg wave, was also reproduced (Plate 245). Some channel shoaling was observed in deeper water, but most material bypassed as indicated by the deposits against the outer arm of the new east breakwater. The area shoaled was reduced from the Base Test results (Plate 72). Plates 247-250 show results of the long-term test. Plate 247 indicates tracer patterns after 2 hr (model time) of a 5-sec, 4-ft, 27-deg wave. Current patterns for this condition are shown in Plate 248. After 10 hr of testing, the gap between the shore and the new east breakwater had closed and a fillet developed (Plate 249). The tracer material was left in place after the 10 hr of testing with the 27-deg wave, and a 5-sec, 7-ft, 304-deg wave was tested for 1 hr to determine the effectiveness of a northwesterly wave in keeping the fillet size minimized, since it would not be desirable to fill to the outer end of the structure. Plate 250 indicates a slight recession of the fillet, starting at the edge of the new east breakwater and extending eastward.

Seiche Tests

68. A period of 0.5 hr was selected for seiche testing since this was a commonly occurring period at Little Lake (see paragraph 21), and it was near the Helmholtz frequency for the channel-harbor system of Little Lake (see paragraph 14). Initially, a seiche height of 0.2 ft was selected for testing. Subsequently a 0.6-ft seiche was reproduced to generate higher currents through the study area and determine sediment shoaling characteristics. Prototype data analysis indicated that median currents at the minimum cross-sectional area of the channel were 0.62 fps, with maximum velocities as great as 4.5 fps. This section will present quantitative measurements of seiche-generated currents in the entrance channel region and photographs of the surface currents. Also, water-level variations with time are shown for the tests conducted.

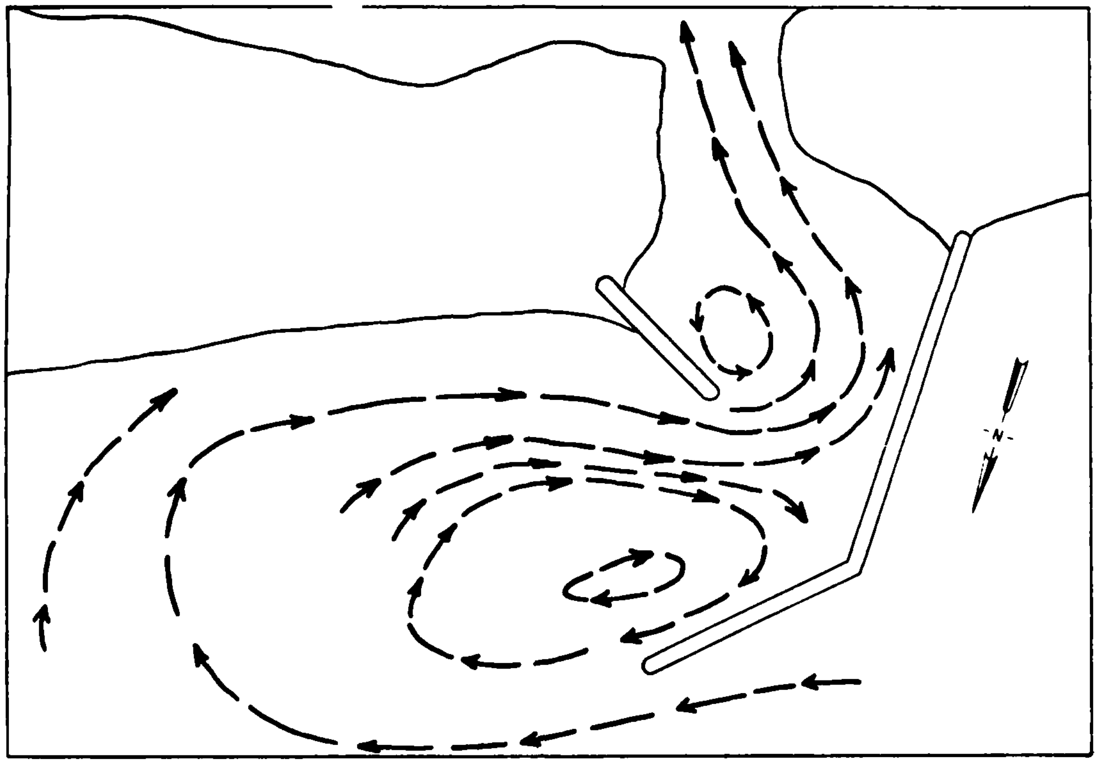
Base Tests

69. Plates 251 and 252 show surface currents for the 0.2-ft, 0.5-hr seiche. Plates 253-260 show surface currents for the 0.6-ft, 0.5-hr seiche at various times throughout one seiche cycle. The cycle was divided into 120 steps for programming of the seiche generator. The photographs were taken every tenth step and every other photograph is shown, i.e., for time-steps 11, 31, 51, 71, 91, and 111. Maximum inflow occurred at time-step 51 and maximum outflow at time-step 111. Currents for the 0.6-ft seiche were increased over those for the 0.2-ft seiche. From the photographs, it is noted that there was usually a channelward-directed current along the short east breakwater. It was especially strong during inflow conditions (Plates 254 and 255) but was also strong during late outflow (Plate 253) due to the eddy circulation developed during outflow conditions. Plates 259 and 260 show flow patterns for the 359-deg, 7-ft, 5-sec wave with the 0.6-ft seiche. Inflow patterns for this condition and the nonwave condition are similar at the entrance between the structures, but the approach flow is stronger near the shoreline and the east breakwater for the wave condition (compare Plates 255 and 259) and reduced near the tip of the west structure. Outflow conditions are similar within the breakwater entrance channel but outside

this region, flow patterns are affected by the wave conditions and there is more flow closer to shore (compare Plates 258 and 260).

70. Figures 27 and 28 show model-prototype comparisons of current patterns at Little Lake Harbor. The top sketches of each figure were derived by Saylor from current drogue measurements and dye releases during a field study in September 1964 and represent current patterns during a westerly storm with seiche action occurring. The model photographs were made reproducing a 0.6-ft seiche with 5-sec, 7-ft waves from 304 deg. Figure 27, showing inflow patterns, showed good reproduction in the model of the flow along the short east breakwater, the eddy region along the inside of the outer leg of the west breakwater, and the eddy region on the inside of the east breakwater. Flow patterns on the outside perimeter of the study area were reproduced well. Figure 28 shows outflow patterns and the eddy along the east breakwater was correctly reproduced as was flow on the perimeter of the study area. The model circulation cell is more circular in shape than that defined from the prototype; however, this is probably a result of the wave direction. No wave direction was mentioned precisely by Saylor, other than to say the patterns represented a storm out of the west. A sharper wave angle in the model would probably elongate the circulation cell. Wave measurements in the prototype indicated drogue measurements were made when a 5-sec, 2.0-m (6.5 ft) wave was occurring, which was about the same as that reproduced in the model.

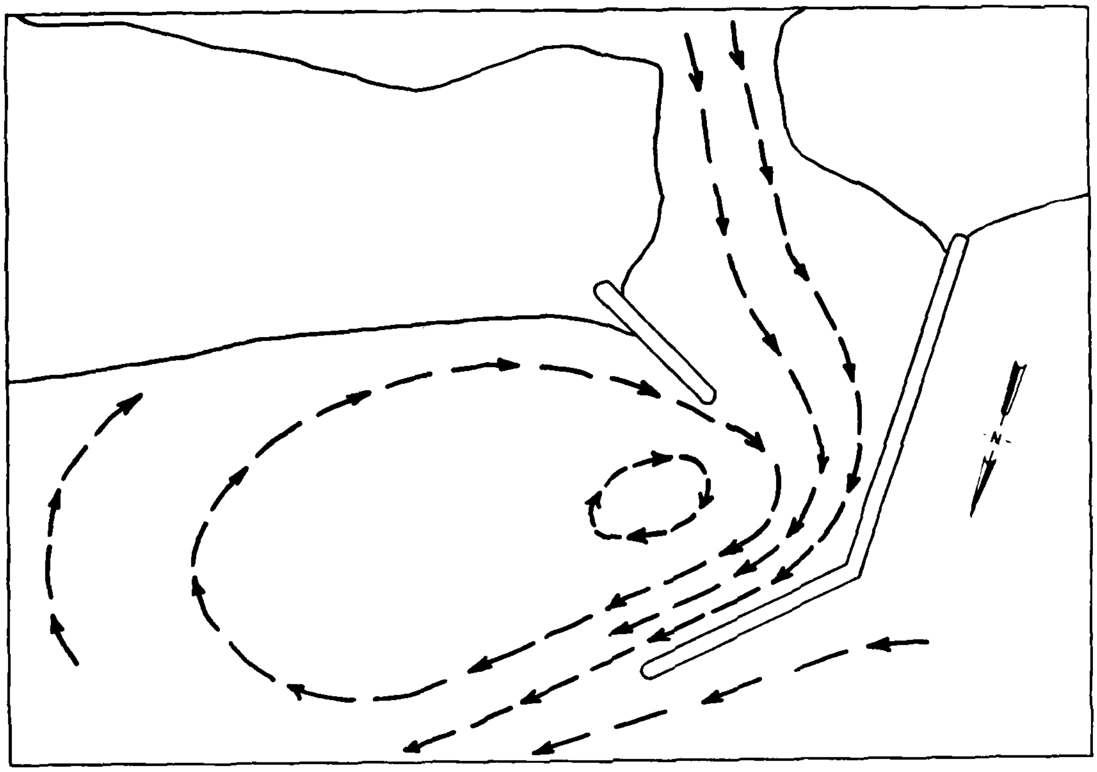
71. Water-surface elevation and velocity measurements were made at the model locations shown in Plate 261. Plate 262 shows water-surface elevation during the 0.2-ft, 0.5-hr seiche. As shown in Plate 262, the seiche amplitude was doubled in the harbor due to Helmholtz resonance. The amplification factor was reduced to about 1.25 (Plate 263) for the larger 0.6-ft seiche. This reduction in amplification is most likely due to the rough shape of the lake oscillation, which was the result of the seiche generator working near its maximum capacity. The result was that other frequencies were present in the input signal (i.e., the Lake Superior seiche). Plates 264 and 265 show velocity measurements made for the 0.2-ft seiche at middepth of the water column.



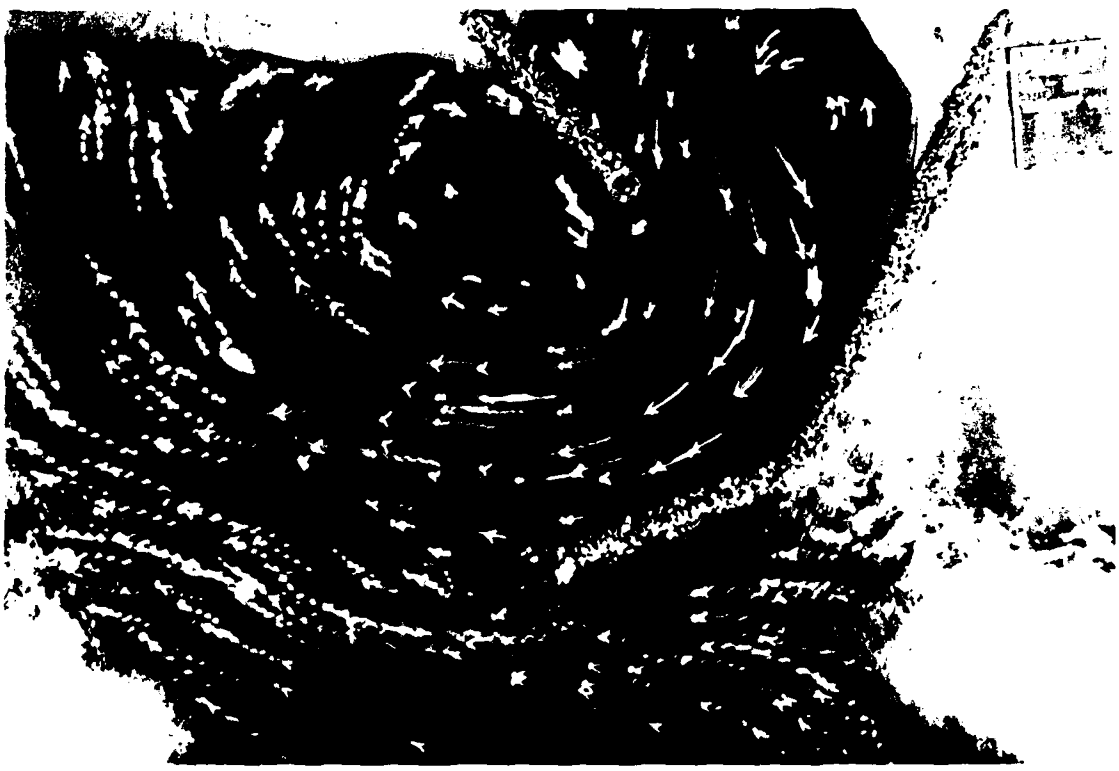
a. Prototype (from Saylor 1966)

b. Model

Figure 27. In-flow current patterns



a. Prototype (from Saylor 1966)



b. Model

Figure 28. Outflow current patterns

Plate 264 indicates maximum velocities at range 1 of just over 2 fps (flowing inward) and fairly uniformly distributed over this minimum-area cross section. Velocities at range 2 (Plate 265) which has a cross-sectional area about twice that of range 1, have maximums of 1.5, 1.0, and 0.8 fps (all flowing outward) at sta 2E, 2C, and 2W, respectively. Base velocities for the 0.6-ft seiche will be shown along with velocities from the plan conditions.

Plan 5

72. Plan 5 was selected for seiche testing, and elevations and current velocities were measured during the initial plan testing. The 0.6-ft seiche was amplified very slightly (about 1 percent) in the harbor and less than that for the base conditions (Plate 266). The bay amplitude was reduced due to some increase in friction resulting from increased channel length and also a shift in the Helmholtz frequency to a longer period. The shift results from an increase in length as noted by examining the Helmholtz equation in paragraph 14. The shift would move the frequency response curve in Plate 8 to the left, but the shift would only be on the order of a few minutes since the incremental increase in channel length would only be a small part of the total channel length. In examining the Helmholtz equation, a 30 percent increase in channel length (from 1,000 ft to 1,300 ft) would increase the Helmholtz period 3.4 min from base conditions. However, once the project is constructed, it could be expected that channel depths would be greater and this would cause a reduction in Helmholtz frequency. For example, if average depths changed from 7.4 ft (1979 conditions) to 10 ft and including the increased channel length in the calculation, the Helmholtz period would be 30.0 min, a minor change from the existing condition of 30.6 min. Velocities for the base and Plan 5 conditions are shown in Plates 267-269. At range 1 (Plate 267), the Plan 5 condition shows slight decreases in the maximums from the base condition. Velocity maximums on the order of 3 fps were observed in each case. Greater changes were noted at range 2 due to flow reorientation (Plate 268).

73. Some bay elevation and current velocity measurements were made for a seiche with waves. Plate 270 shows the bay setup of about

0.2 ft due to the 5-sec, 7-ft, 27-deg wave. Velocities were taken only at range 1 for the Plan 5 condition with seiche and, for reference, waves and are compared with base velocities with seiche and no waves. A substantial reduction in maximum velocities for Plan 5 is noted in Plate 271. Plate 272 indicates about a 0.6-ft setup due to the 9-sec, 8-ft, 304-deg wave and Plate 273 shows greater velocity decreases at range 1 than for the 27-deg wave.

Plan 8B

74. Plate 274 indicates about a 15 percent amplification of the 0.6-ft lake seiche in the harbor for Plan 8B. With the gap between the Plan 8B structure and the shoreline closed, as is the assumed case after buildup of the fillet, the amplification was reduced so that the harbor water-level range was just below that of the lake seiche range (Plate 275) for the 0.5-hr period. Velocities at range 1 showed a shift from the west side of the channel to the east side on the inflow (Plate 276). Maximum currents were reduced for the Plan 8 condition from base currents by small amounts except for sta 1E during inflow. Range 2 did not show significant changes in current magnitudes at any of the stations (Plate 277). Plate 278 shows the velocities at the entrance gap between the breakwaters at the center of the channel. Maximum outflow currents of 2.4 fps were measured.

75. With the shore-breakwater gap closed (by the fillet), there are a few variations in velocities at ranges 1 and 2 (Plates 279 and 280) relative to the gap open data (mostly in the peak velocities at range 1 on inflow). With the gap closed, maximum outflow velocity at sta 3C increased from 2.4 fps to 3.0 fps (Plate 281).

76. Plates 282-287 show surface currents for Plan 8B (gap open) and Plates 288-293 show the surface currents for the gap closed condition. The Plan 8B alignment primarily affected outflow currents when compared with base conditions (compare Plates 258, 287, and 293). Once the gap was closed, outflow currents showed good flow lines existing between the caissons. With the gap open, some currents were directed at the east caisson. At time-step 111 for this maximum outflow condition, there were 2.0-fps currents exiting through the gap into the lake

(Plate 287). During maximum inflow (time-step 51), patterns are not significantly changed near the central region of the photographs (i.e., near existing structures), but there are currents up to 2 fps through the gap (compare Plates 255, 284, and 290).

PART V: CONCLUSIONS

77. Based on results of this hydraulic model investigation, it is concluded that:

a. Shoaling problems for the existing conditions are mainly due to the influx of sediment along the east breakwater and eastern edge of the channel. Sediment may enter the channel via this route for any wave approach. For waves from the north to west sector, this channelward movement is the result of the circulation gyre developed in the lee of the west breakwater. This clockwise gyre begins at a point of separation at the shoreline east of the east breakwater (the location dependent on wave angle, but on the order of 600 ft). The wave-generated flow follows the shoreline and east breakwater toward the east edge of the channel, then turns lakeward and exits parallel to the outer leg of the west breakwater in an easterly direction. These patterns of flow and paths of sediment movement were observed in Base Tests of the model. Shoaling off the tip of the west breakwater was observed in the model for certain wave conditions, similar to those of the prototype. Shoaling also was observed on the channel side of the inner leg of the west breakwater (due to overtopping waves and suspended sediment). For larger wave conditions, a large percentage of tracer bypassed the entrance on the second bar.

b. Spectral analysis of water-level records indicate that seiche activity with frequencies near that of the Helmholtz frequency for the channel-bay system of Little Lake (about 2 cph) occurs regularly. The water-level fluctuation in the bay may then be greater than that of Lake Superior and currents of significant magnitude may be generated through the entrance channel.

c. Current patterns with seiche and wind-wave activity reproduced in the model had similar flow patterns to the prototype.

d. The seiche-generated currents did not significantly change shoaling patterns of testing performed without seiche activity. The main effect was slightly more penetration of sediment bayward along the entrance channel.

e. Whenever a plan extended to the bar that bypasses the harbor, the plan intercepted sediment and shoaling of the channel occurred (i.e., Plans 1, 3, and 4).

f. If either the eastward or westward structure protruded farther lakeward than the other, heavy channel shoaling usually occurred (i.e., Plans 1, 1A, 3, 4, and 5). This

was the result of eddy development on the downwave side of the structure.

g. Plan 2, with a flared outer leg on the new east breakwater, tended to funnel sediment moving toward the entrance from the east into the channel. Wave reflection aided this transport toward the entrance channel.

h. Plans 6, 7, and 10 permitted sediments from the east to enter the channel relatively easily but Plan 8 reduced the movement into the entrance channel.

i. The Plan 8 configuration performed well in reducing channel shoaling (see paragraphs 63 and 67) and provided good bypassing characteristics in both directions for the larger wave conditions. Shortening the shoreward leg of the structure (Plan 8A) did not adversely impact its ability to naturally close the gap between the shore and the structure. Also, the addition of a caisson on the lakeward terminus (Plan 8B) did not adversly affect shoaling patterns. The caisson would better define the entrance during rough lake conditions. The Plan 8B configuration will permit a "straight in" approach for boat traffic into the protected area between the breakwaters.

j. Plan 8B reduced seiche oscillations in the harbor and velocities in the entrance channel for the 0.5-hr-period, 0.6-ft seiche relative to the base conditions.

REFERENCES

Bajorunas, L., and Duane, D. B. 1967 (Dec). "Shifting Offshore Bars and Harbor Shoaling," Journal of Geophysical Research, American Geophysical Union, Vol 22, No. 24, pp 6195-6205.

Ball, J. W., and Brasfeild, C. W. 1967 (Dec). "Expansion of Santa Barbara Harbor, California; Hydraulic Model Investigation," Technical Report No. 2-805, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Bottin, R. R., Jr., and Chatham, C. E., Jr. 1975 (Nov). "Design for Wave Protection, Flood Control, and Prevention of Shoaling, Cattaraugus Creek Harbor, New York; Hydraulic Model Investigation," Technical Report H-75-18, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Dai, Y. B., and Jackson, R. A. 1966 (Jun). "Design for Rubble-Mound Breakwaters, Dana Point Harbor, California; Hydraulic Model Investigation," Technical Report No. 2-725, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Kureth, C. L., Jr. 1978. "The Importance of the Sediment Budget Method," Proceedings, Coastal Zone 1978, American Society of Civil Engineers, New York, pp 1720-1737.

Miles, J. W. 1948. "Coupling of a Cylindrical Tube to a Half-Infinite Space," Journal of Acoustical Society of America, Vol 20, pp 652-664.

Noda, E. K. 1971 (Mar). "Final Report, Coastal Movable-Bed-Scale Model Relationship," Report TC-191, Tetra Tech, Inc., Pasadena, Calif.

Resio, D. T., and Vincent, C. L. 1978 (Jun). "Design Wave Information for the Great Lakes; Report 5, Lake Superior," Technical Report H-76-1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Saylor, J. H. 1966 (Jan). "Currents at Little Lake Harbor, Lake Superior," Research Report No. 1-1, U. S. Lake Survey, Department of the Army, Lake Survey District, CE, Detroit, Mich.

Saylor, J. H., and Upchurch, S. B. 1970 (Aug). "Bottom Stability and Sedimentary Processes at Little Lake Harbor, Lake Superior," Research Report No. 2-1, U. S. Lake Survey, Department of the Army, Lake Survey District, CE, Detroit, Mich.

Seelig, W. N., and Sorensen, R. M. 1977 (Jul). "Hydraulics of Great Lakes Inlets," Technical Paper No. 77-8, U. S. Army Coastal Engineering Research Center, Fort Belvoir, Va.

U. S. Army Engineer District, Detroit. 1959 (Oct). "Harbor of Refuge at Little Lake, Michigan, General Design Memorandum," Detroit, Mich.

________. 1977. "Hydraulic and Geological Analysis for the Little Lake Design Deficiency Study at Little Lake Harbor, Michigan," Detroit, Mich.

Table 1

Simultaneous Data at Lake and Dock Gages

Data Set	Record Length,* Days	Date
1	5.34	6/4/79 - 6/9/79
2	54.36	6/12/79 - 8/5/79
3	21.74	8/16/79 - 9/7/79
4	1.08	9/17/79 - 9/18/79
5	4.75	9/24/79 - 9/29/79
6	4.15	9/29/79 - 10/3/79
7	3.58	10/3/79 - 10/6/79
8	1.57	10/8/79 - 10/9/79
9	0.96	10/29/79 - 10/30/79

* Both gages operative with good data.

Table 2

Observed Modes of Oscillation of Lake Superior

Mode No.	Period, hr	Frequency, cph
1 Longitudinal	7.8	0.13
2	4.8	0.21
3	3.6	0.28
4	--	--
5	3.0	0.33
6	2.2	0.45
7	1.7	0.59
8	1.5	0.67
9	1.2	0.83
10	1.14	0.88
1 Transverse	--	--
2	--	--
?*	0.95	1.05
?	0.66 to 0.68	1.49
?	0.58	1.72
?	0.52 to 0.53	1.92
?	0.49	2.04

* ? = other observed periods, mode unknown.
(From Seelig and Sorensen 1977)

Table 3

Seiche Height and Period Occurrence for 187 Days, 1979

	Period, hr												
Height, ft	0.08	0.17	0.25	0.33	0.42	0.50	0.58	0.67	0.75	0.83	0.92	1.00	TOTAL
Lake, West Wall Occurrences													
0.00 - 0.05	0	48*	338	479	297	249	153	64	38	13	2	2	1683
0.05 - 0.10	0	58	303	319	209	275	200	121	45	14	5	5	1554
0.10 - 0.15	0	30	160	189	171	178	170	109	34	17	4	3	1065
0.15 - 0.20	0	16	83	91	87	115	109	47	32	10	2	3	595
0.20 - 0.25	0	7	35	50	53	51	46	37	15	3	3	1	301
0.25 - 0.30	0	3	15	14	24	20	24	22	5	3	2	0	132
0.30 - 0.35	0	3	11	16	11	15	17	7	0	1	2	0	83
0.35 - 0.40	0	1	4	10	9	9	9	4	5	0	1	1	53
0.40 - 0.45	0	1	3	3	9	4	4	2	0	1	0	0	27
0.45 - 0.50	0	1	0	4	4	6	2	0	0	0	0	0	17
> 0.50	0	0	5	9	9	14	9	4	3	2	0	0	55
TOTAL	0	168	957	1184	883	936	743	417	177	64	21	15	5565
State Dock Occurrences													
0.00 - 0.05	0	69*	267	367	511	569	524	250	137	88	45	192	3019
0.05 - 0.10	0	6	47	113	234	252	175	69	34	16	4	6	956
0.10 - 0.15	0	5	26	96	236	329	204	85	40	12	4	1	1038
0.15 - 0.20	0	1	39	84	199	326	182	83	36	12	3	1	966
0.20 - 0.25	0	2	23	71	194	274	193	70	29	10	2	0	868
0.25 - 0.30	0	3	18	50	131	241	142	53	16	8	0	1	663
0.30 - 0.35	0	3	7	26	76	158	101	27	12	4	1	2	417
0.35 - 0.40	0	1	7	13	53	108	77	27	12	3	0	0	301
0.40 - 0.45	0	1	0	11	28	58	40	26	6	3	1	0	174
0.45 - 0.50	0	1	2	13	27	29	28	9	1	3	0	0	113
> 0.50	0	0	4	11	29	54	40	14	6	2	1	0	161
TOTAL	0	92	440	855	1718	2398	1706	713	329	161	61	203	8676

* Number of occurrences.

Table 4

Table of Extremes Estimates, ft

Grid Location, 15.33; Lat = 46.77, Long. = 85.39;

Little Lake Harbor

Shoreline Grid Point 52				
Occurrence Interval, yr	Angle Classes 1	2	3	ALL
		Winter		
5	9.2(1.3)*	14.4(1.3)	16.7(1.3)	17.4(0.4)
10	10.5(1.8)	16.1(1.8)	18.0(1.8)	18.4(0.6)
20	11.2(2.2)	17.4(2.2)	19.4(2.2)	19.5(0.7)
50	12.1(2.8)	18.7(2.8)	20.3(2.8)	20.4(0.9)
100	12.8(3.2)	19.4(3.2)	21.0(3.2)	21.1(1.0)
		Spring		
5	3.5(1.4)	9.1(1.4)	11.0(1.4)	11.1(0.5)
10	5.1(1.9)	11.8(1.9)	11.8(1.9)	11.9(0.7)
20	6.3(2.4)	14.2(2.4)	12.6(2.4)	14.3(0.9)
50	7.5(3.0)	16.1(3.0)	13.0(3.0)	16.2(1.1)
100	8.3(3.4)	17.3(3.4)	13.4(3.4)	17.4(1.3)
		Summer		
5	1.6(1.6)	6.9(1.6)	8.9(1.6)	9.5(0.6)
10	3.0(2.1)	9.8(2.1)	10.5(2.1)	10.8(0.8)
20	3.6(2.6)	11.8(2.6)	11.8(2.6)	11.9(1.0)
50	4.6(3.2)	14.1(3.2)	13.1(3.2)	14.2(1.3)
100	5.2(3.7)	15.4(3.7)	13.8(3.7)	15.5(1.5)
		Fall		
5	5.9(1.4)	15.1(1.4)	15.1(1.4)	15.7(0.6)
10	7.9(1.8)	16.1(1.8)	17.1(1.8)	17.4(0.8)
20	8.9(2.3)	16.7(2.3)	18.4(2.3)	18.5(1.0)
50	10.5(2.8)	17.7(2.8)	19.7(2.8)	19.7(1.3)
100	11.2(3.3)	18.0(3.3)	20.7(3.3)	20.8(1.5)

* Heights are in feet; number in parentheses is standard deviation estimate.
(From Resio and Vincent 1978)

Table 5

Significant Period by Angle Class and Wave Height

Grid Location 15.33; Lat = 46.77, Long. = 85.39, Little Lake Harbor

Shoreline Grid Point 52			
	Significant Period, sec		
Wave Height, ft	Angle Class 1	Angle Class 2	Angle Class 3
1	2.8	3.6	3.5
2	4.4	4.6	4.6
3	5.1	5.2	5.3
4	5.5	5.6	6.0
5	6.0	6.0	6.4
6	6.3	6.3	6.7
7	6.5	6.6	7.0
8	6.8	6.9	7.4
9	7.0	7.2	7.7
10	7.3	7.4	8.0
11	7.5	7.7	8.3
12	7.8	8.0	8.6
13	8.0	8.3	9.0
14	8.3	8.6	9.3
15	8.5	8.9	9.6
16	8.8	9.2	9.9
17	9.0	9.5	10.2
18	9.3	9.8	10.6
19	9.5	10.1	10.9
20	9.8	10.4	11.2
21	10.0	10.6	11.5
22	10.3	10.9	11.8
23	10.5	11.2	12.2
24	10.8	11.5	12.5
25	11.0	11.8	12.8

(From Resio and Vincent 1978)

Table 6

Little Lake Test Conditions

Test No.	Direction deg	Period sec	Wave Height ft	Seiche	Plan	Remarks
1	278	7	6.5	No	Base	
2	278	7	6.5	No		
3	278	7	4.5	No		
4	278	7	4.5	0.2 ft		
5	40	5	4.5	No		
6	330	7	10	No		
7	40	5	7	0.2 ft		
8		5	7	No		
9		5	4			Dye test only
10		5	7			
11		7	5			
12	330	5	4			
13		5	7			
14		7	6			
15		7	12			
16		9	10			
17		9	21			
18	304	5	4			
19		5	7			
20		7	5			
21		7	10			
22		9	8			
23		9	17			
24	278	5	4			
25		5	7			
26		7	5			
27		7	10			
28		9	8			
29		9	17			
30	27	5	4			

(Continued)

Table 6 (Continued)

Test No.	Direction deg	Period sec	Wave Height ft	Seiche	Plan	Remarks
31	27	5	7	No	Base	
32		7	5			
33		7	10			
34		9	8			
35		9	16			
36	40	5	4			
37		5	7			
38		7	5			
39		7	10			
40		9	8			
41		9	16			
42	359	5	4			
43		5	7			
44		7	6			
45		7	12			
46		9	10			
47		9	21			
48	304	7	10	0.2 ft		Same as T-21 but with seiche
49	27	7	10	0.2 ft		Same as T-33 but with seiche
50	304	7	10	0.6 ft		Same as T-21 without seiche and T-48 with 0.2-ft seiche
51	27	7	10	0.6 ft		Same as T-31 without seiche and T-49 with 0.2-ft seiche
52	27	5	4	0.6 ft		Same as T-30 but without seiche
53	27	7	10	No	4	
54	304	7	10	No	4	
55	304	5	7	No	4	
56	304	9	8	No	4	

(Continued)

(Sheet 2 of 5)

Table 6 (Continued)

Test No.	Direction deg	Period sec	Wave Height ft	Seiche	Plan	Remarks
57	27	5	7	No	4	
58	27	5	7		3	
59	27	7	10			
60	304	5	7			
61	304	7	10			
62	304	9	8			
63	27	5	7		2	
64	27	7	10			
65	304	5	7			
66	304	7	10			
67	304	9	8			
68	27	5	7		1	
69	27	7	10			
70	304	5	7			
71	304	7	10			
72	304	9	8			
73	27	5	7		1A	
74	27	7	10			
75	304	5	7			
76	304	7	10			
77	304	9	8			
78	27	5	7		1B	
79	27	7	10			
80	304	5	7			
81	304	7	10			
82	304	9	8			
83	27	5	7		5	
84	27	7	10			
85	304	5	7			
86	304	7	10			
87	304	9	8			

(Continued)

(Sheet 3 of 5)

Table 6 (Continued)

Test No.	Direction deg	Period sec	Wave Height ft	Seiche	Plan	Remarks
88	27	5	7	0.6 ft	5	Same as T-83 but with 0.6-ft seiche
89	304	9	8	0.6 ft	5	Same as T-87 but with 0.6-ft seiche
90	27	5	7	No	6	
91	27	7	10			
92	304	5	7			
93	304	7	10			
94	304	9	8			
95	27	5	7		8	
96	27	7	10			
97	304	5	7			
98	304	7	10			
99	304	9	8			
100	27	5	7		7	
101	27	7	10			
102	304	5	7			
103	304	7	10			
104	304	9	8			
105	27	5	4		9	Test duration 8 hr
105A			4		9	Test duration 2 hr
106			7		8A	
107			7		10	
108			7		8A	Repeat of Test 106
109	27	5	7		8A	Slight change to east jetty
110	27	5	7		8B	
111	304	9	8		8B	
112	27	7	10		8B	
113	27/304	5	4		8B	27 deg for 10 hr and 304 deg for 1 hr

(Continued)

(Sheet 4 of 5)

Table 6 (Concluded)

Test No.	Direction deg	Period sec	Wave Height ft	Seiche	Plan	Remarks
114	40	5	7	No	8B	
115	40	7	10	No	8B	
116	359	5	7	No	8B	
117	359	7	10	No	8B	

(Sheet 5 of 5)

Table 7

Comparison Wave Heights for Base Test and Plans 1-5

for Waves from 27-deg Direction, +1.0 ft swl

	Test Wave		Wave Height, ft, for Gages					
Plan	Period sec	Height ft	1	2	3	4	5	6
BT	5.0	4.0	<0.1	0.4	2.5	3.7	4.5	5.9
		7.0	0.1	0.5	1.7	2.7	5.5	4.5
	7.0	5.0	0.1	0.5	1.6	2.4	5.7	7.6
		10.0	0.1	0.7	2.5	3.3	6.1	6.7
	9.0	8.0	0.1	0.7	1.6	2.7	7.7	5.7
		16.0	0.1	0.6	1.9	2.4	8.1	7.1
1	5.0	4.0	<0.1	0.2	0.8	0.7	2.2	2.0
		7.0	<0.1	0.3	1.2	1.0	2.7	4.3
	7.0	5.0	<0.1	0.3	1.9	1.8	4.2	6.2
		10.0	0.1	0.5	1.7	2.4	3.9	5.9
	9.0	8.0	0.1	0.4	1.1	3.2	4.2	8.1
		16.0	0.1	0.4	1.2	2.9	5.8	9.3
2	5.0	4.0	0.1	0.5	1.4	1.3	1.9	3.7
		7.0	0.1	0.5	1.3	1.4	2.9	5.5
	7.0	5.0	0.1	0.4	2.0	1.7	2.8	6.1
		10.0	0.2	0.7	1.8	2.1	1.7	7.0
	9.0	8.0	0.2	0.4	1.5	3.0	2.9	7.2
		16.0	0.1	0.4	1.1	2.5	2.4	8.1
3	4.8	4.0	<0.1	0.3	0.9	1.3	1.8	3.6
	5.0	7.0	<0.1	0.2	1.0	1.3	2.9	4.3
	7.0	5.0	0.1	0.6	2.0	2.6	3.4	6.2
		10.0	0.1	0.4	1.2	1.9	2.9	5.4
	9.0	8.0	0.1	0.3	0.8	2.6	2.8	6.1
		16.0	0.1	0.5	1.0	2.3	2.8	7.0
4	5.0	4.0	<0.1	<0.1	0.1	0.2	1.2	0.5
		7.0	<0.1	<0.1	0.2	0.2	2.9	0.6
	7.0	5.0	<0.1	0.1	0.7	0.5	3.2	1.9
		10.0	<0.1	0.1	0.5	0.5	1.8	1.3
	9.0	8.0	<0.1	0.2	0.5	1.0	2.5	2.3
		16.0	<0.1	0.1	0.4	0.9	3.6	2.5
5	5.0	4.0	0.1	0.4	1.2	1.8	0.7	3.7
		7.0	0.2	0.9	1.8	2.8	1.0	6.4
	7.0	5.0	0.1	0.8	1.9	2.1	1.5	8.3
		10.0	<0.1	0.5	1.4	1.8	1.7	6.7
	9.0	8.0	0.2	0.5	1.5	2.7	1.3	7.3
		16.0	<0.1	0.3	0.9	1.8	2.0	6.0

(Continued)

Table 7 (Concluded)

Test Wave								
Plan	Period sec	Height ft	Wave Height, ft, for Gages 7	8	9	11	10	12
BT	5.0	4.0	3.5	3.6	3.9	4.0	3.9	3.6
		7.0	4.3	6.0	5.3	7.9	5.8	6.4
	7.0	5.0	6.8	8.3	6.1	7.9	6.3	7.4
		10.0	7.4	9.1	7.7	11.2	6.6	6.4
	9.0	8.0	7.7	6.8	6.5	13.9	6.5	6.8
		16.0	8.1	7.6	7.5	12.1	7.4	8.1
1	5.0	4.0	3.9	4.5	5.3	3.7	2.4	2.0
		7.0	6.1	6.3	4.9	8.4	6.0	6.0
	7.0	5.0	10.1	6.2	7.3	7.5	7.1	4.9
		10.0	7.5	7.9	8.3	11.7	6.8	4.7
	9.0	8.0	6.9	6.9	7.4	11.6	7.6	5.6
		16.0	8.8	8.6	8.6	11.0	8.5	5.9
2	5.0	4.0	4.6	5.7	4.9	4.5	4.5	3.7
		7.0	5.4	6.4	6.0	7.7	6.2	3.5
	7.0	5.0	7.4	7.7	6.5	7.0	7.4	4.6
		10.0	8.7	7.7	7.3	11.1	7.8	5.7
	9.0	8.0	7.5	7.6	7.2	13.0	7.4	5.3
		16.0	7.2	7.6	7.0	12.5	7.7	7.3
3	4.8	4.0	4.4	3.2	3.9	4.3	3.2	3.4
	5.0	7.0	5.2	4.6	5.5	6.4	5.0	3.7
	7.0	5.0	8.2	6.8	6.4	7.7	6.9	4.8
		10.0	6.1	7.7	6.4	11.2	6.4	5.4
	9.0	8.0	7.1	6.1	6.3	11.6	6.4	6.1
		16.0	8.2	7.9	7.2	11.2	7.4	6.2
4	5.0	4.0	4.1	2.9	2.9	3.0	0.2	0.5
		7.0	4.4	4.5	4.3	5.5	0.6	1.1
	7.0	5.0	8.9	7.5	5.7	10.1	1.4	2.3
		10.0	8.0	7.8	5.4	14.9	1.5	1.8
	9.0	8.0	7.1	5.7	6.0	15.7	1.8	2.3
		16.0	7.9	6.9	7.6	12.3	1.9	1.8
5	5.0	4.0	3.9	5.8	5.0	3.4	3.2	3.1
		7.0	6.2	6.5	6.7	5.9	5.9	6.4
	7.0	5.0	8.8	9.0	7.5	7.8	7.9	7.0
		10.0	8.2	10.3	7.5	10.1	7.6	6.5
	9.0	8.0	7.4	7.1	6.5	12.7	6.8	6.2
		16.0	7.4	7.5	7.7	10.9	7.7	7.3

Table 8

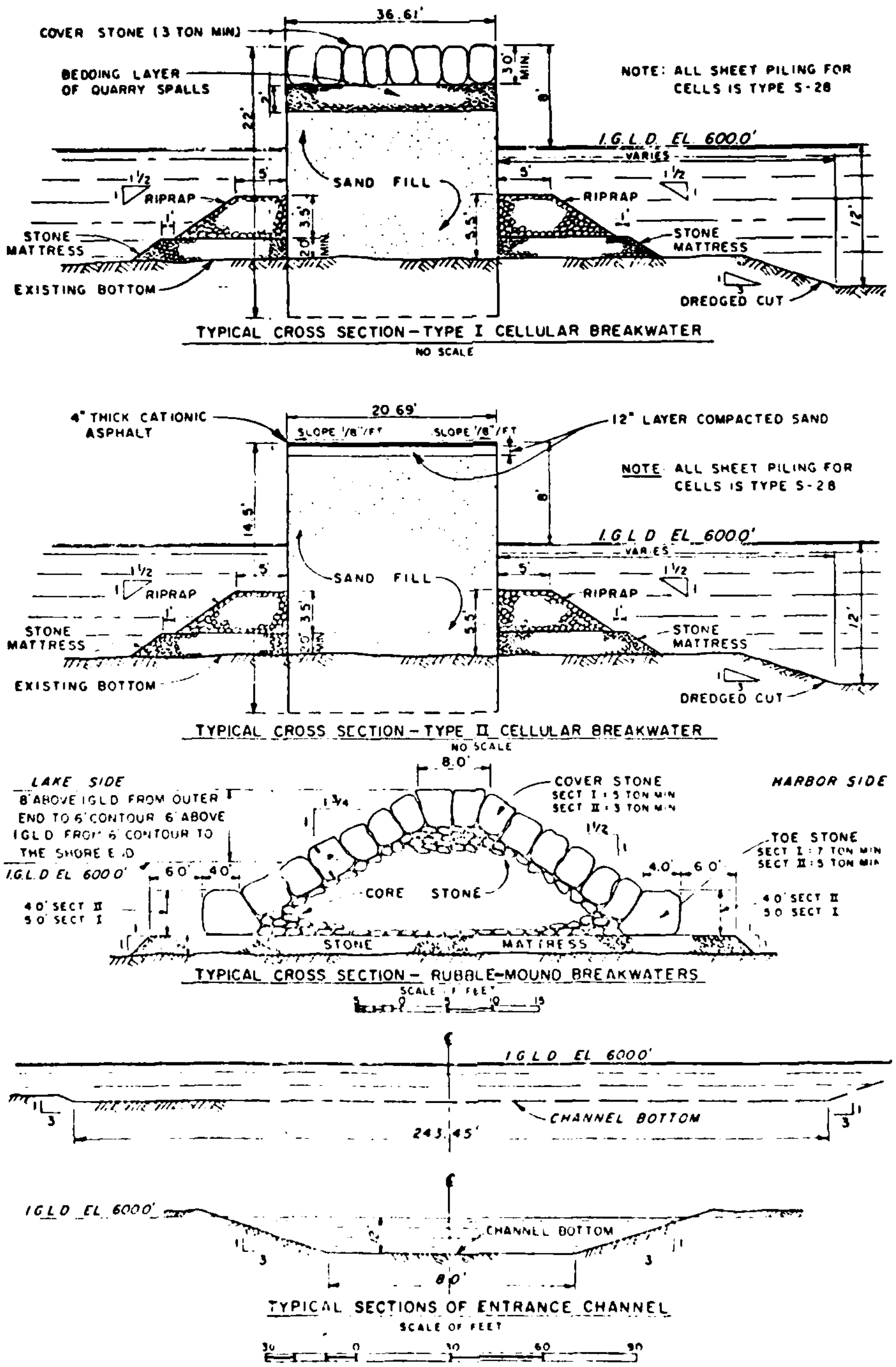
Comparison Wave Heights for Base Test and Plans 1-5 for Waves from 304-deg Direction, +1.0 ft swl

Plan	Test Wave Period sec	Test Wave Height ft	Wave Height, ft, for Gages 1	2	3	4	5	6
BT	5.0	4.0	<0.1	0.1	0.4	0.9	5.5	6.4
		7.0	<0.1	0.2	0.7	0.9	5.4	4.8
	7.0	5.0	<0.1	0.2	0.7	1.1	6.2	6.8
		10.0	<0.1	0.2	0.5	0.8	6.6	5.0
	9.0	8.0	<0.1	0.2	0.6	0.9	7.5	6.5
		17.0	<0.1	0.3	0.8	1.0	7.1	6.5
1	5.0	4.0	<0.1	0.2	0.7	1.0	1.2	4.0
		7.0	0.1	0.2	0.5	0.7	1.0	4.9
	7.0	5.0	<0.1	0.3	0.8	1.0	1.3	5.8
		10.0	0.1	0.3	1.1	1.5	1.3	5.7
	9.0	8.0	0.1	0.4	0.9	2.2	1.4	6.3
		17.0	<0.1	0.3	0.8	2.6	1.7	9.2
2	5.0	4.0	<0.1	0.2	0.6	1.3	0.8	7.2
		7.0	<0.1	0.2	0.4	0.8	0.6	4.8
	7.0	5.0	<0.1	0.3	1.2	1.2	0.8	5.6
		10.0	0.1	0.5	1.2	1.7	1.2	7.3
	9.0	8.0	0.1	0.4	1.2	2.5	1.3	7.7
		17.0	0.1	0.4	0.8	2.7	1.2	7.5
3	5.0	4.0	<0.1	0.1	0.3	0.7	0.5	3.2
		7.0	<0.1	0.2	0.4	0.8	0.6	3.1
	7.0	5.0	<0.1	0.3	1.2	1.5	0.9	3.7
		10.0	<0.1	0.3	1.0	1.3	0.7	2.4
	9.0	8.0	<0.1	0.3	0.5	1.9	1.3	5.6
		17.0	0.1	0.3	0.8	1.5	1.0	5.2
4	5.0	4.0	<0.1	0.2	0.5	0.7	0.2	2.7
		7.0	<0.1	0.2	0.3	0.5	0.4	2.6
	7.0	5.0	<0.1	0.3	0.9	1.0	0.6	2.1
		10.0	<0.1	0.3	1.2	1.2	1.1	2.3
	9.0	8.0	0.1	0.3	0.7	1.2	0.7	2.7
		17.0	0.1	0.2	0.6	1.4	0.9	3.4
5	5.0	4.0	<0.1	0.2	0.4	0.4	1.2	5.1
		7.0	<0.1	0.1	0.3	0.7	1.3	4.7
	7.0	5.0	<0.1	0.2	0.6	0.7	2.1	4.5
		10.0	<0.1	0.1	0.7	1.0	2.1	5.4
	9.0	8.0	<0.1	0.2	0.6	1.2	2.0	6.1
		17.0	<0.1	0.2	0.7	1.4	2.6	6.7

(Continued)

Table 8 (Concluded)

	Test Wave		Wave Height, ft, for Gages					
Plan	Period sec	Height ft	7	8	9	11	10	12
BT	5.0	4.0	5.5	7.5	6.0	4.0	5.8	6.1
		7.0	6.5	8.1	4.6	7.4	4.9	7.9
	7.0	5.0	6.5	8.0	7.6	6.0	5.9	7.7
		10.0	8.3	7.1	6.0	10.9	6.7	7.9
	9.0	8.0	9.4	7.7	7.7	13.5	6.9	8.5
		17.0	10.1	10.3	7.9	11.2	7.2	9.8
1	5.0	4.0	5.1	6.3	5.3	7.7	6.9	3.9
		7.0	6.2	5.0	6.0	10.8	8.0	3.4
	7.0	5.0	8.6	8.7	7.2	7.7	5.7	3.2
		10.0	6.8	10.0	7.3	9.3	8.5	3.6
	9.0	8.0	10.9	8.3	9.7	13.2	7.7	4.1
		17.0	10.3	10.5	10.2	10.9	9.9	4.3
2	5.0	4.0	5.5	7.4	7.0	4.8	6.2	8.1
		7.0	6.1	5.4	4.8	9.2	5.5	7.8
	7.0	5.0	7.7	7.7	6.0	9.7	6.1	7.5
		10.0	8.9	8.5	8.1	11.5	5.6	7.1
	9.0	8.0	9.1	10.2	7.3	11.3	5.7	7.1
		17.0	10.1	10.8	8.1	11.4	6.6	7.6
	5.0	4.0	6.4	6.9	6.3	6.4	5.0	7.5
		7.0	5.7	5.4	3.6	8.9	5.3	7.3
	7.0	5.0	10.4	7.3	7.6	10.8	8.2	7.8
		10.0	7.8	10.3	7.0	7.6	5.7	7.1
	9.0	8.0	8.1	8.5	7.3	12.1	6.7	6.5
		17.0	9.9	10.5	8.2	9.0	7.4	7.8
4	5.0	4.0	4.9	7.3	6.8	7.9	3.2	1.7
		7.0	5.3	4.8	4.3	8.8	3.3	2.7
	7.0	5.0	8.6	7.8	6.5	10.6	4.6	2.5
		10.0	8.9	9.2	6.7	11.6	4.2	2.2
	9.0	8.0	8.0	9.7	8.2	10.8	4.2	2.3
		17.0	10.0	10.0	7.8	10.8	3.6	2.3
5	5.0	4.0	6.7	7.3	5.5	6.5	7.0	9.5
		7.0	6.2	4.4	4.2	8.8	5.6	7.4
	7.0	5.0	7.5	6.8	6.6	12.4	5.7	7.3
		10.0	8.2	10.5	6.5	9.1	6.8	8.1
	9.0	8.0	8.9	9.0	9.6	12.9	7.1	9.2
		17.0	10.4	10.9	8.2	9.9	7.8	10.4



TYPICAL CROSS SECTIONS OF BREAKWATERS AND CHANNEL

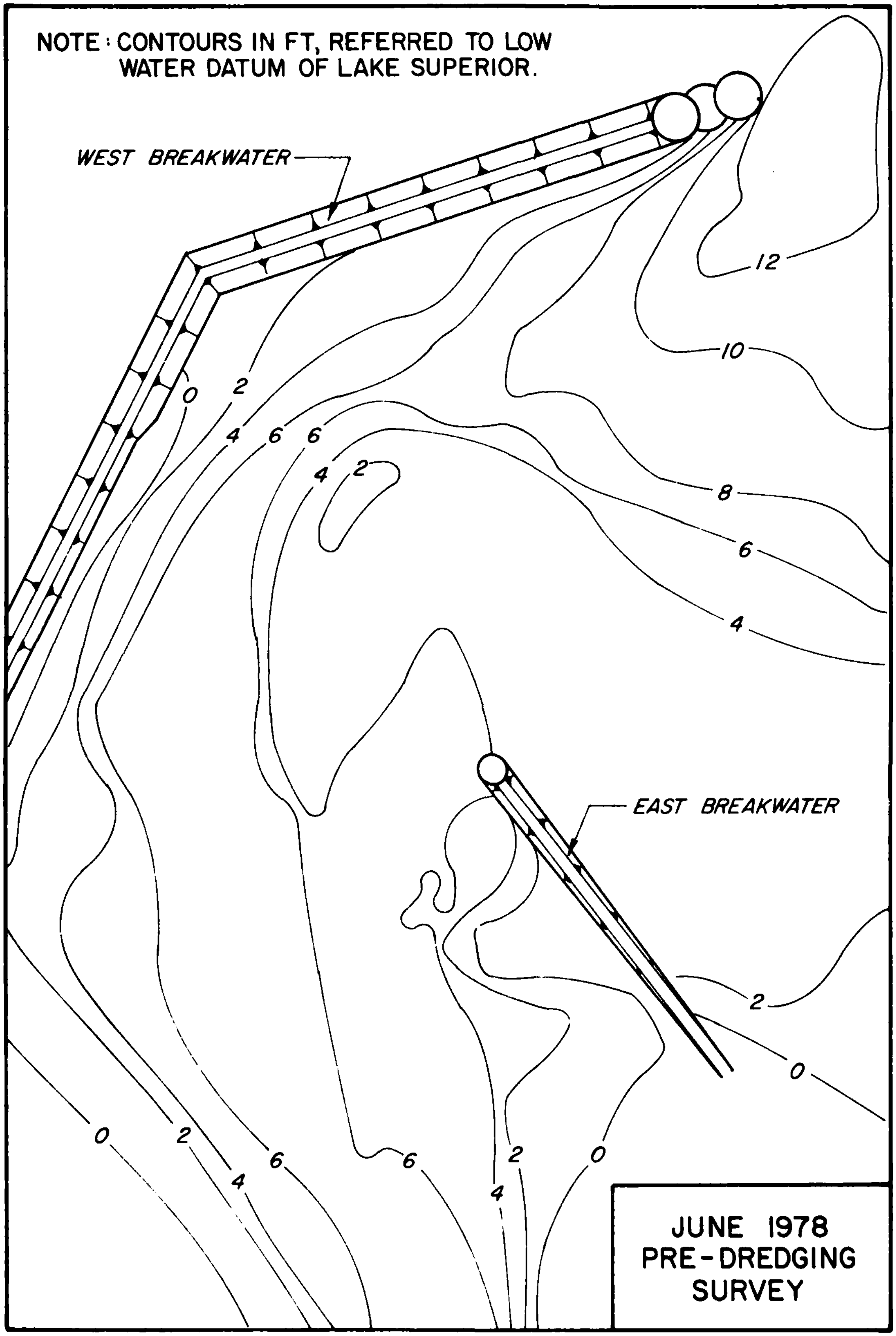

NOTE: CONTOURS IN FT, REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
WEST BREAKWATER
EAST BREAKWATER
12
10
8
6
4
2
0
JUNE 1978 PRE-DREDGING SURVEY

PLATE 2

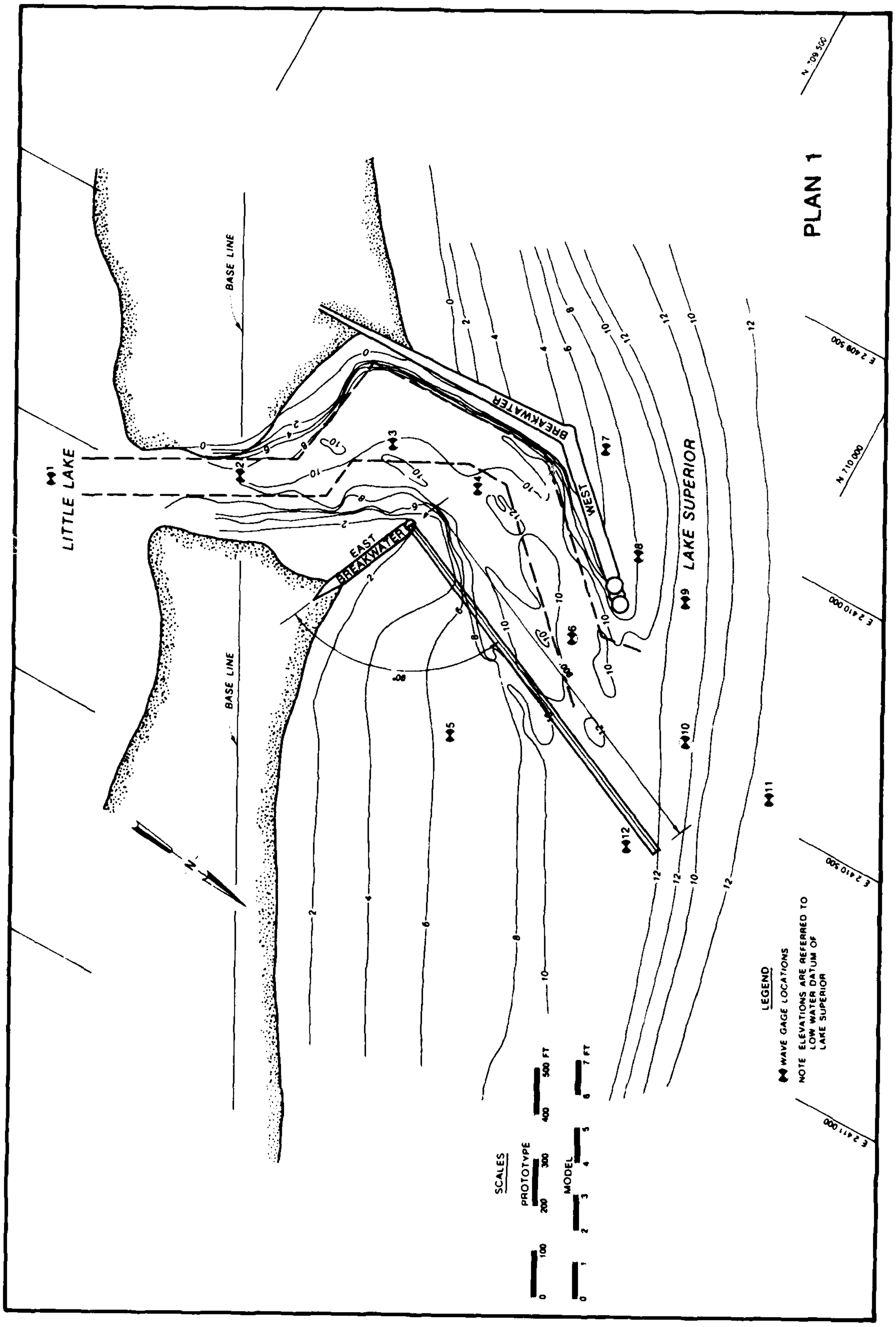

PLAN 1
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N 709 500
N 710 000
E 2 408 500
E 2 410 000
E 2 410 500
E 2 411 000
LEGEND
WAVE GAGE LOCATIONS
NOTE ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 3

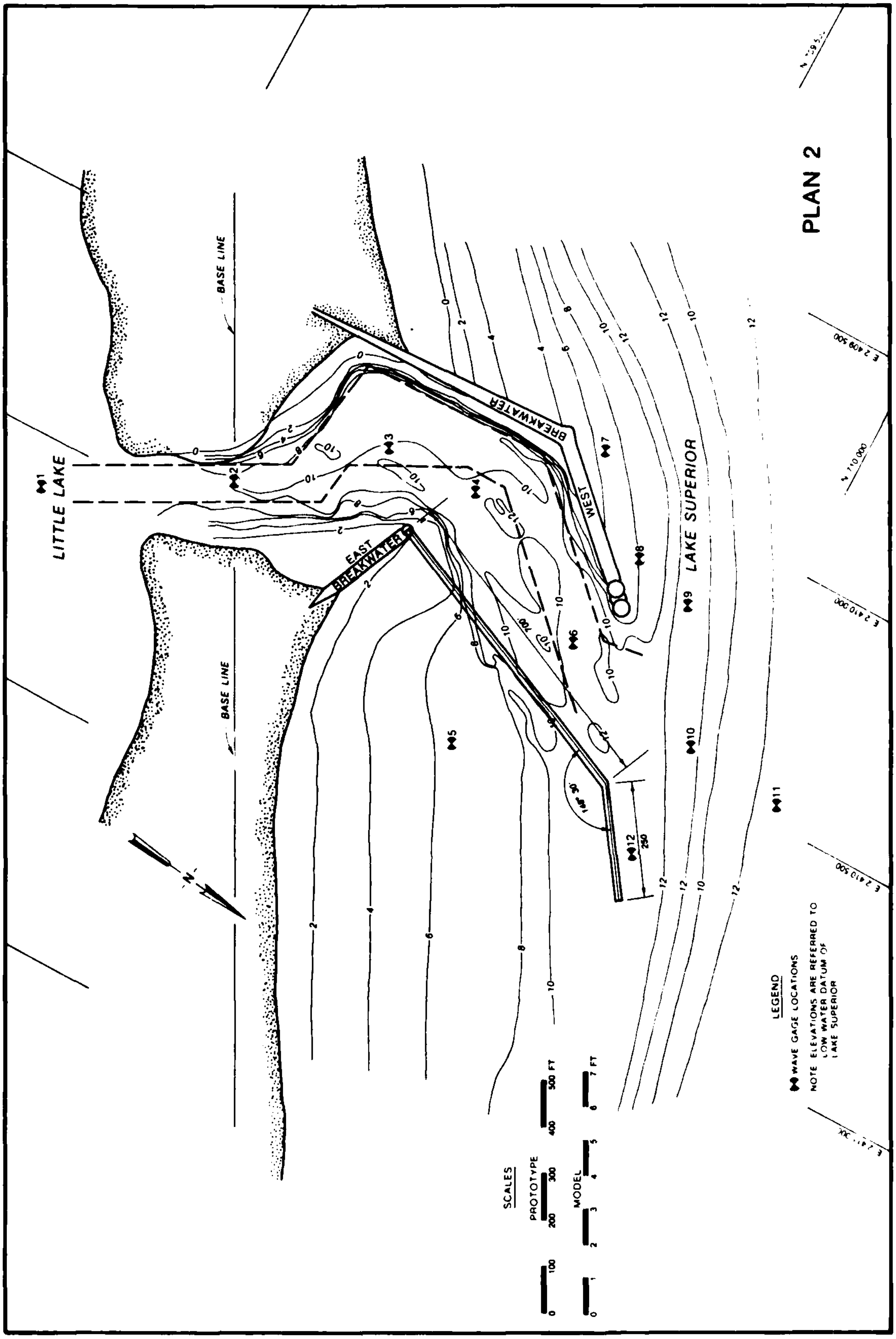

PLAN 2
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
E 2 409 500
N 710 000
E 2 410 000
E 2 410 500
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
WAVE GAGE LOCATIONS
NOTE ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR

PLATE 4

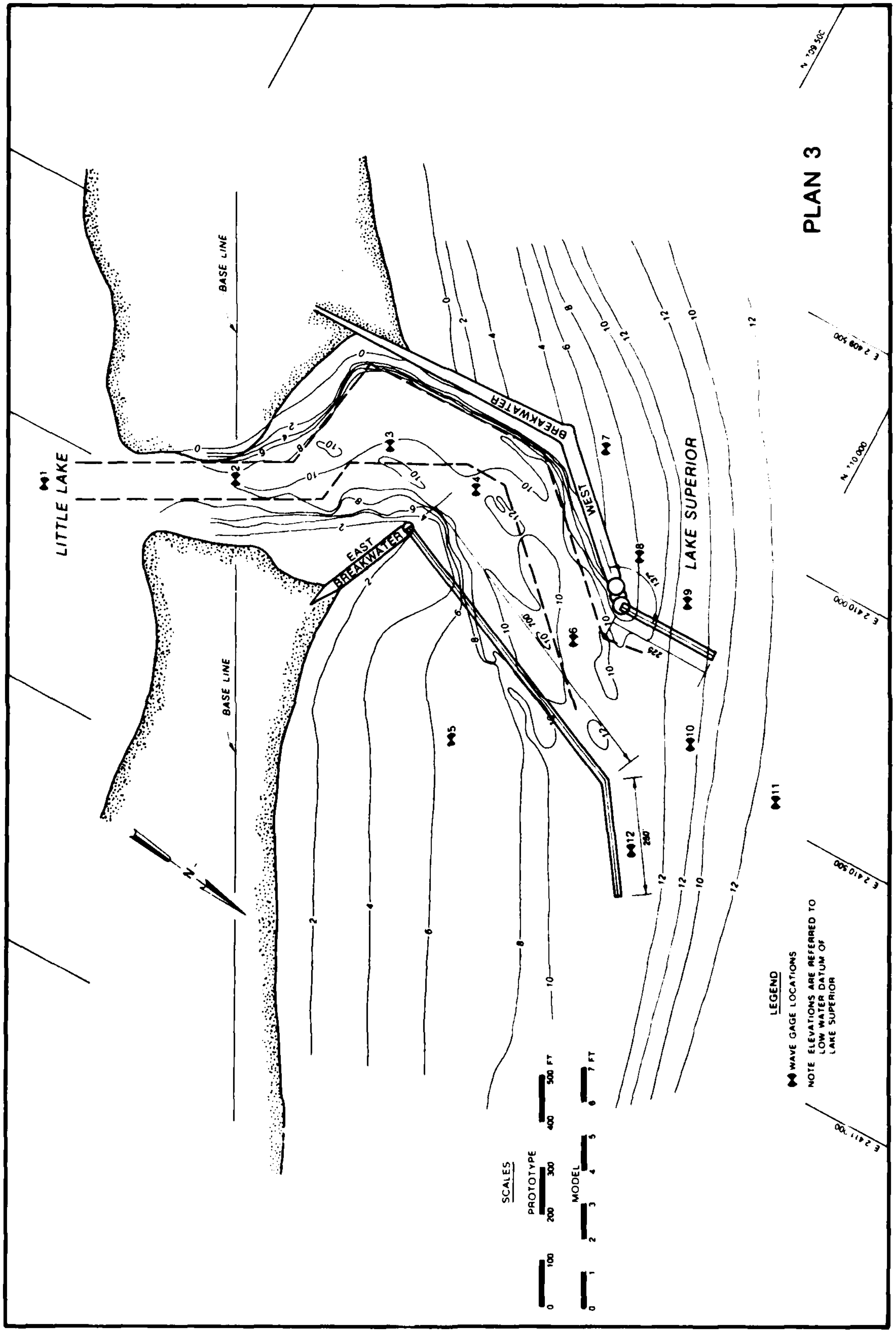

PLAN 3
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
SCALES
PROTOTYPE
MODEL
LEGEND
WAVE GAGE LOCATIONS
NOTE ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR

PLATE 5

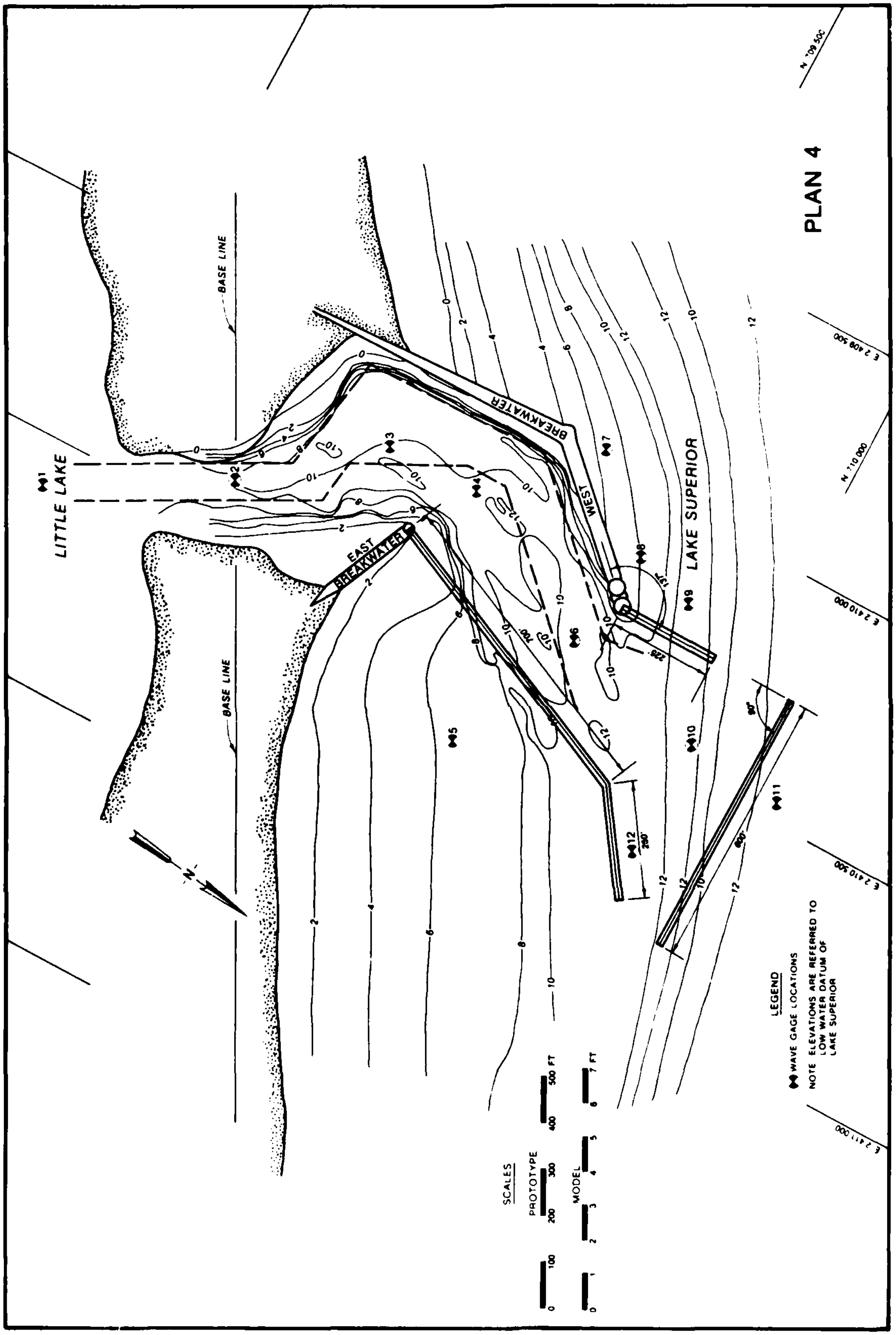
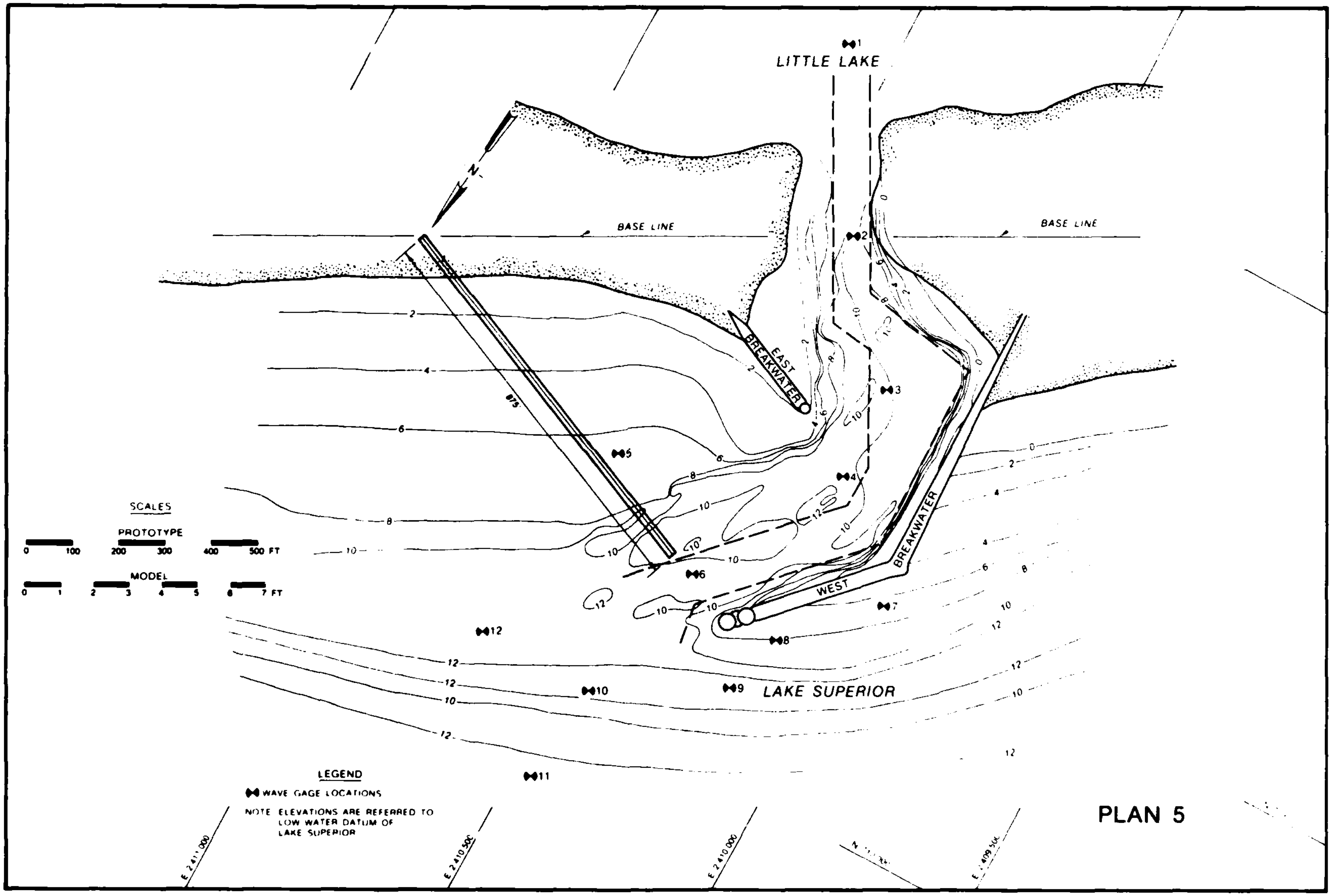
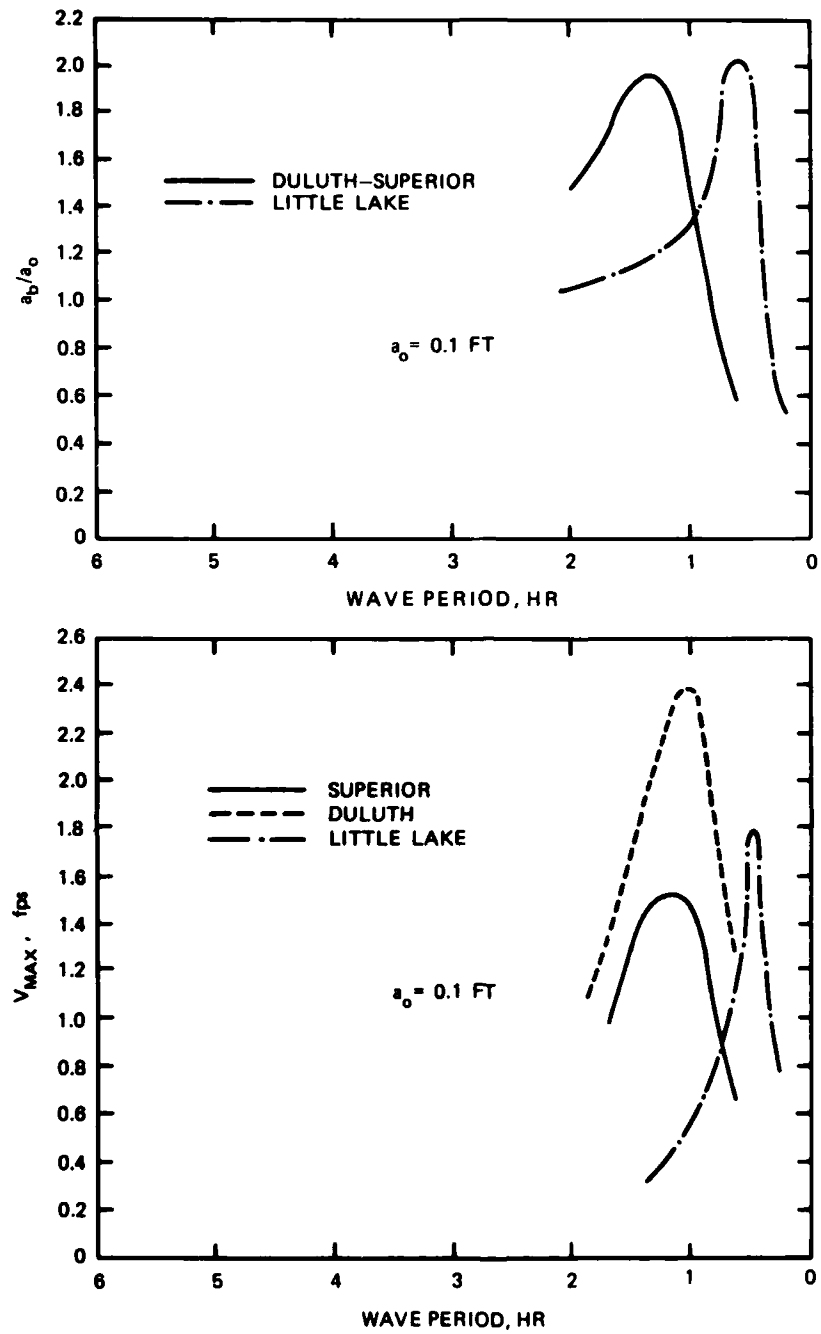

PLAN 4
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
N
LEGEND
WAVE GAGE LOCATIONS
NOTE ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 6



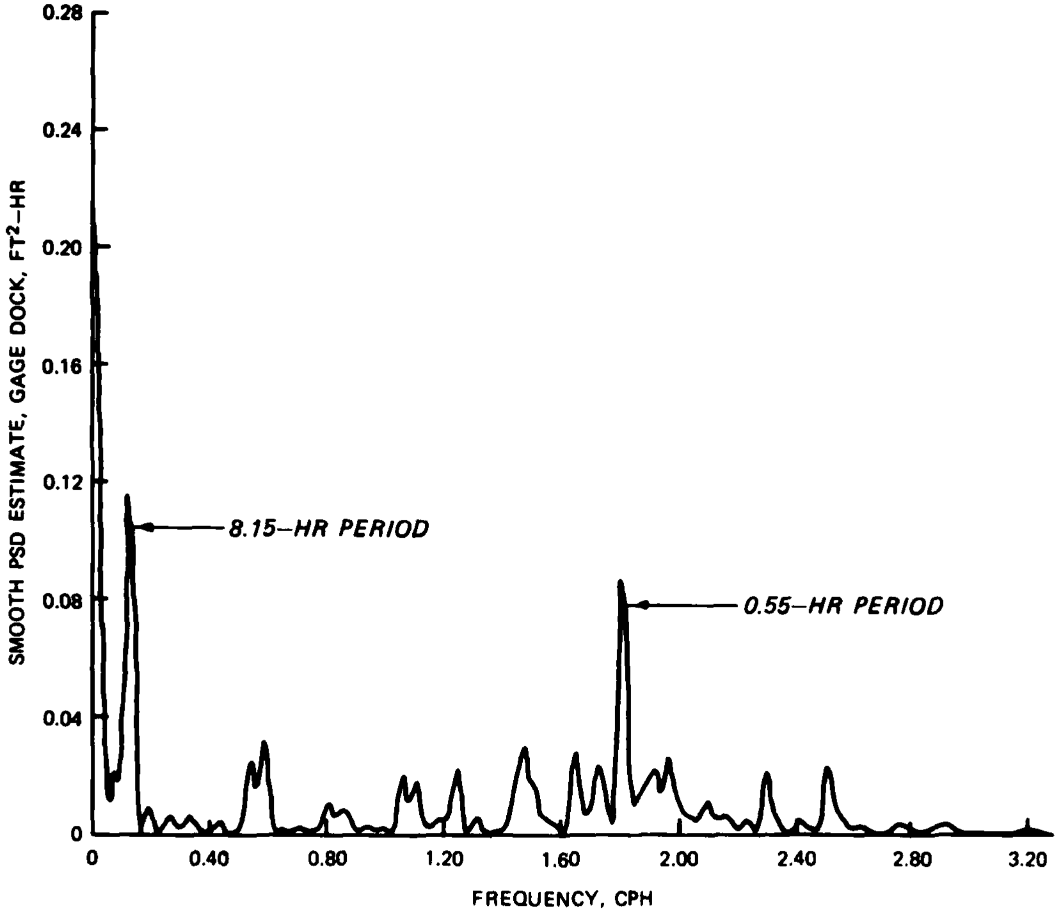
PLAN 5
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
WAVE GAGE LOCATIONS
NOTE ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR
E 2 410 500
E 2 410 000

PLATE 7



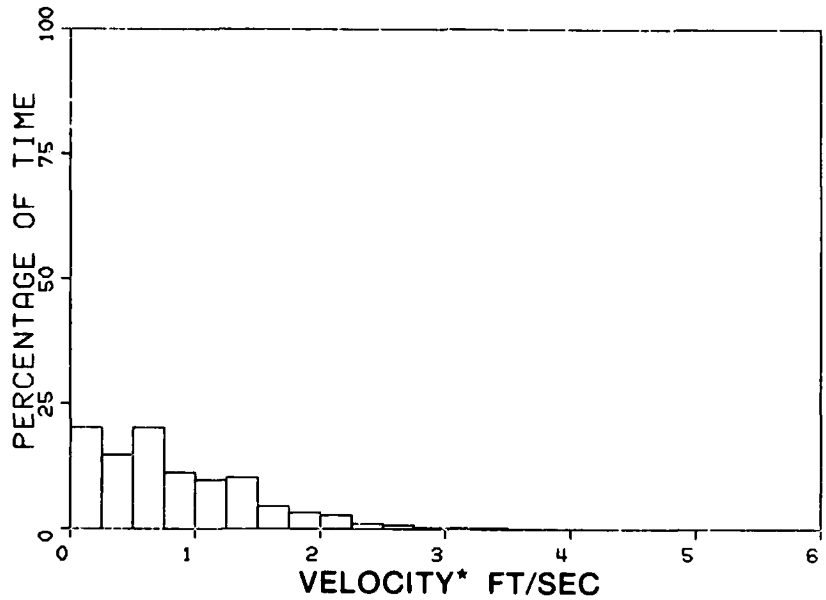
(FROM SEELIG AND SORENSEN 1977)

PREDICTED RESPONSE OF INLET-BAY SYSTEMS ON LAKE SUPERIOR TO MONOCHROMATIC FORCING WITH AMPLITUDE OF 0.1 FT

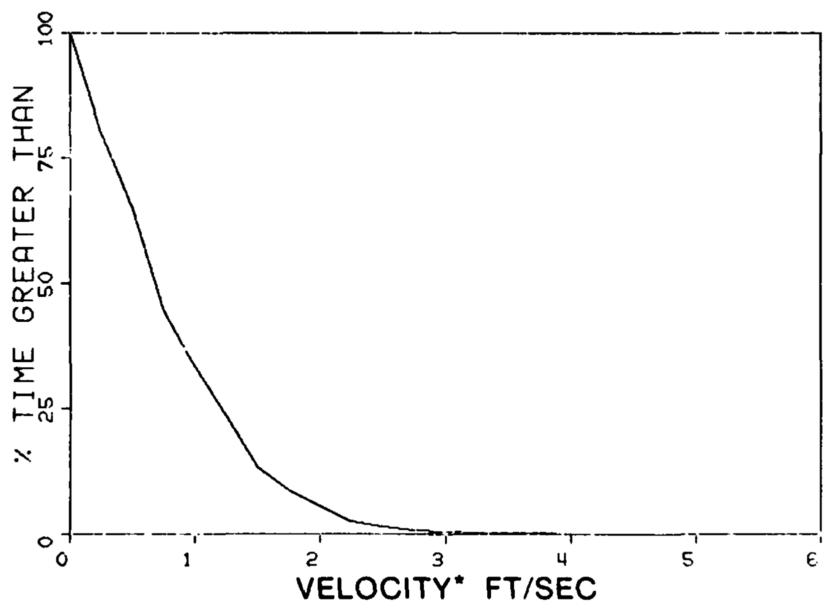


POWER SPECTRAL DENSITY BEFORE
FILTERING LOW FREQUENCIES
12-15 JUN 1979

PLATE 9



VELOCITY HISTOGRAM

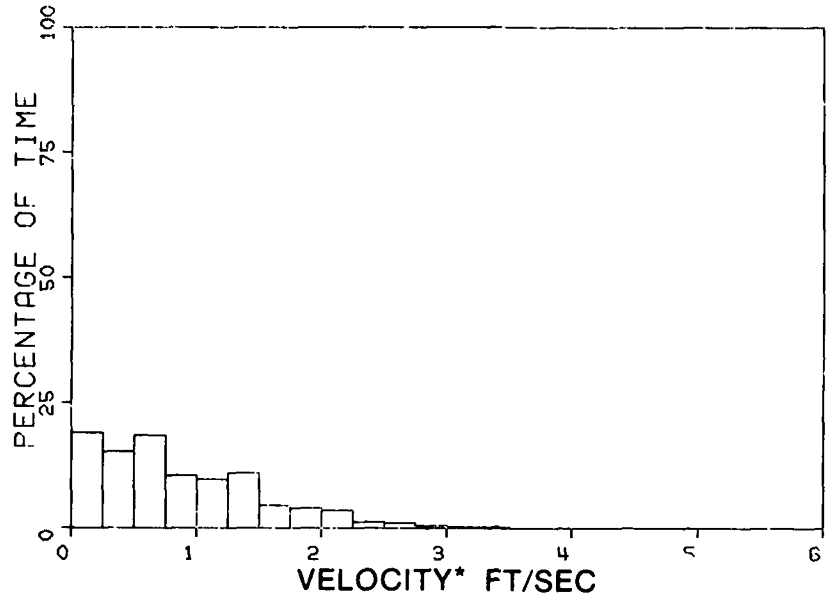


CUMULATIVE VELOCITIES

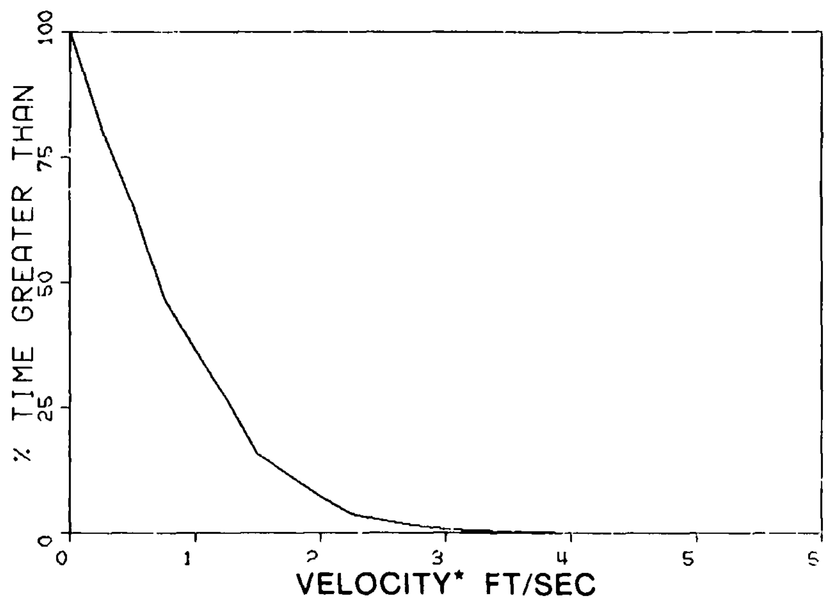
*AVERAGE VELOCITY AT MINIMUM CROSS SECTION OF CHANNEL.

SEICHE-GENERATED
VELOCITY MAGNITUDES
4-9 JUN 1979
DATA SET 1

PLATE 10



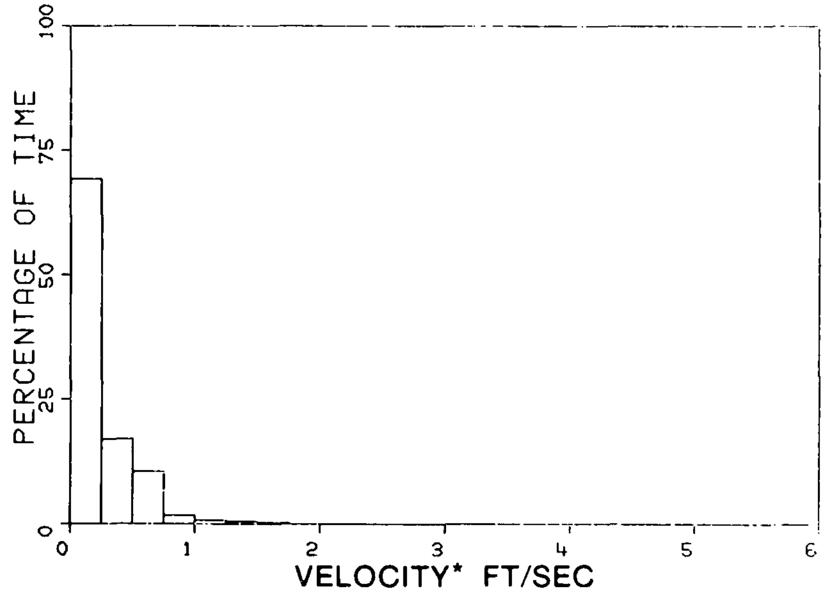
VELOCITY HISTOGRAM



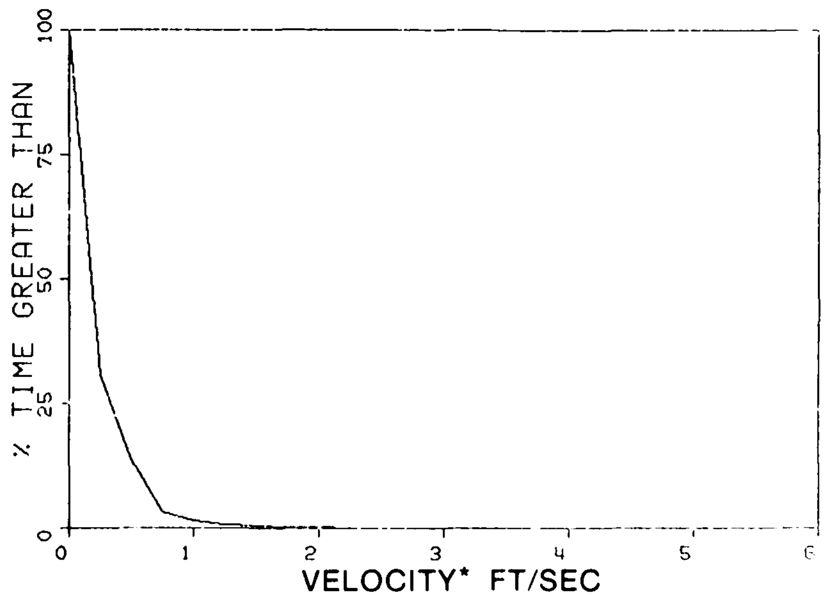
CUMULATIVE VELOCITIES

*AVERAGE VELOCITY AT MINIMUM CROSS SECTION OF CHANNEL.

SEICHE-GENERATED
VELOCITY MAGNITUDES
16 AUG-SEP 1979
DATA SET 3



VELOCITY HISTOGRAM

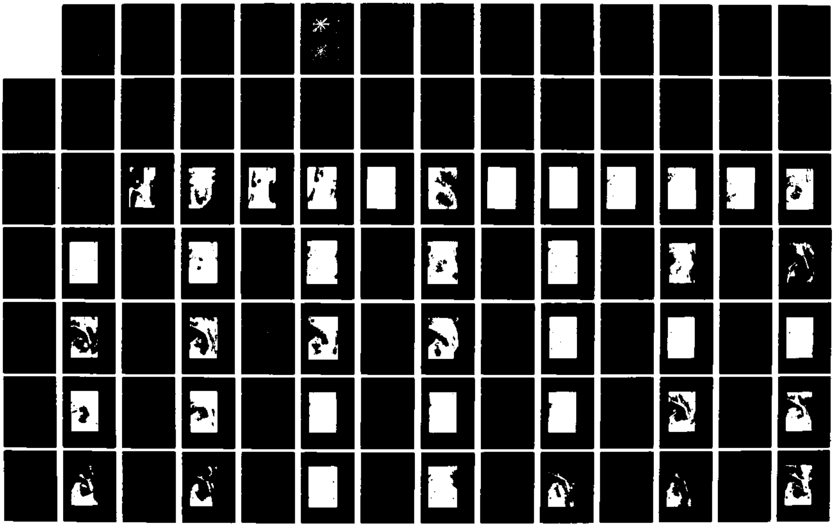


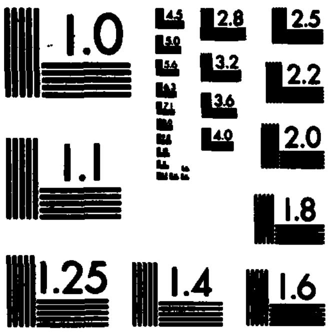
CUMULATIVE VELOCITIES

*AVERAGE VELOCITY AT MINIMUM CROSS SECTION CHANNEL

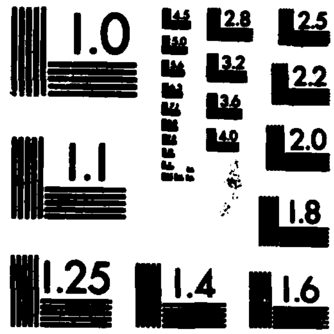
SEICHE-GENERATED
VELOCITY MAGNITUDES
17-18 SEP 1979
DATA SET 4

AD-A120 776 PREVENTION OF SHOALING AT LITTLE LAKE HARBOR MICHIGAN 2/4
HYDRAULIC MODEL INV..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS HYDRA..
UNCLASSIFIED W C SEABERGH ET AL. JUL 82 WES/TR/HL-82-16 F/G 13/2 NL

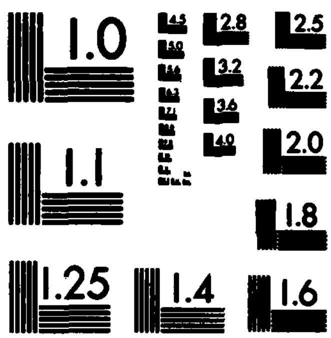




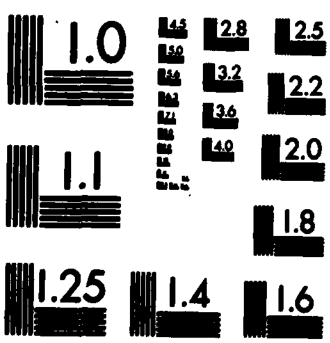
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



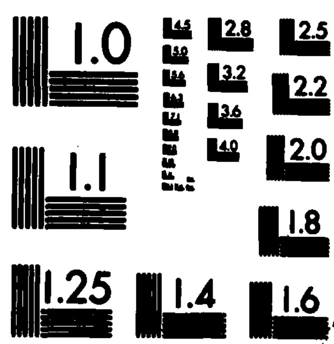
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



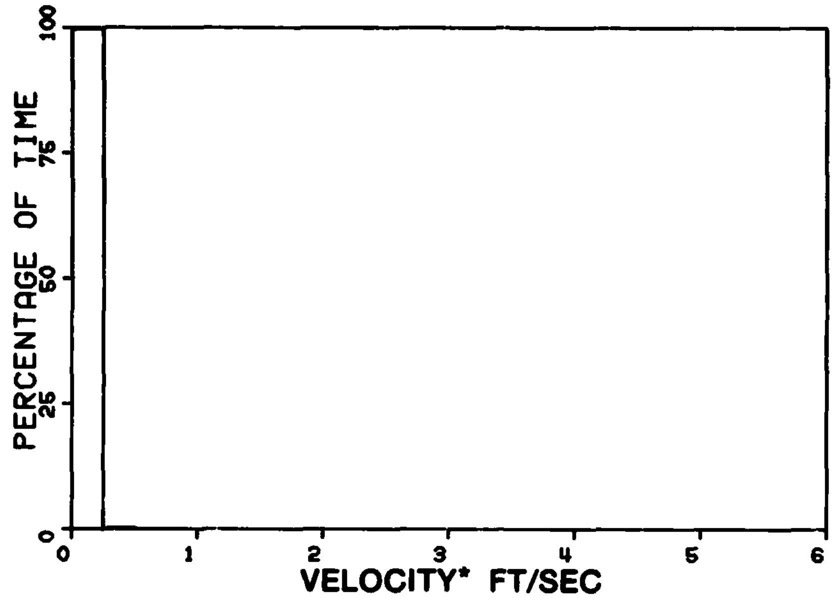
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



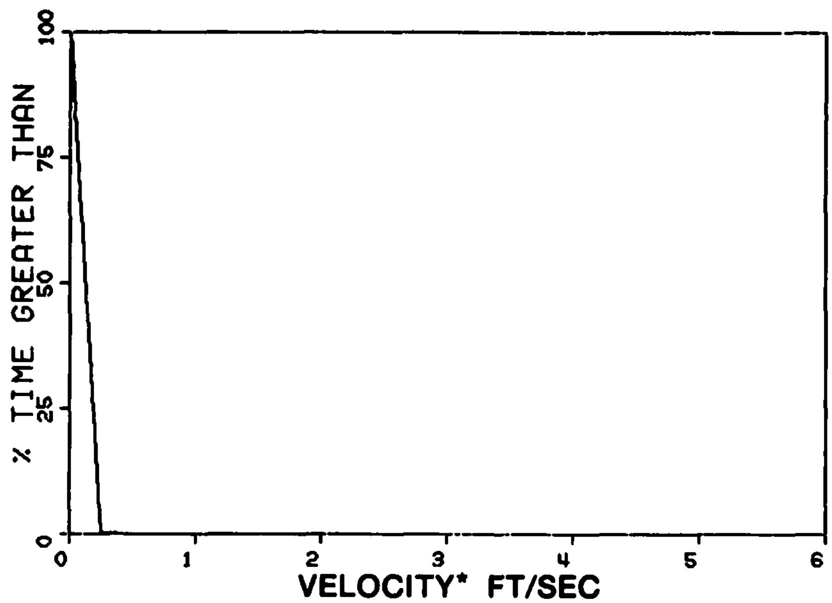
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



VELOCITY HISTOGRAM

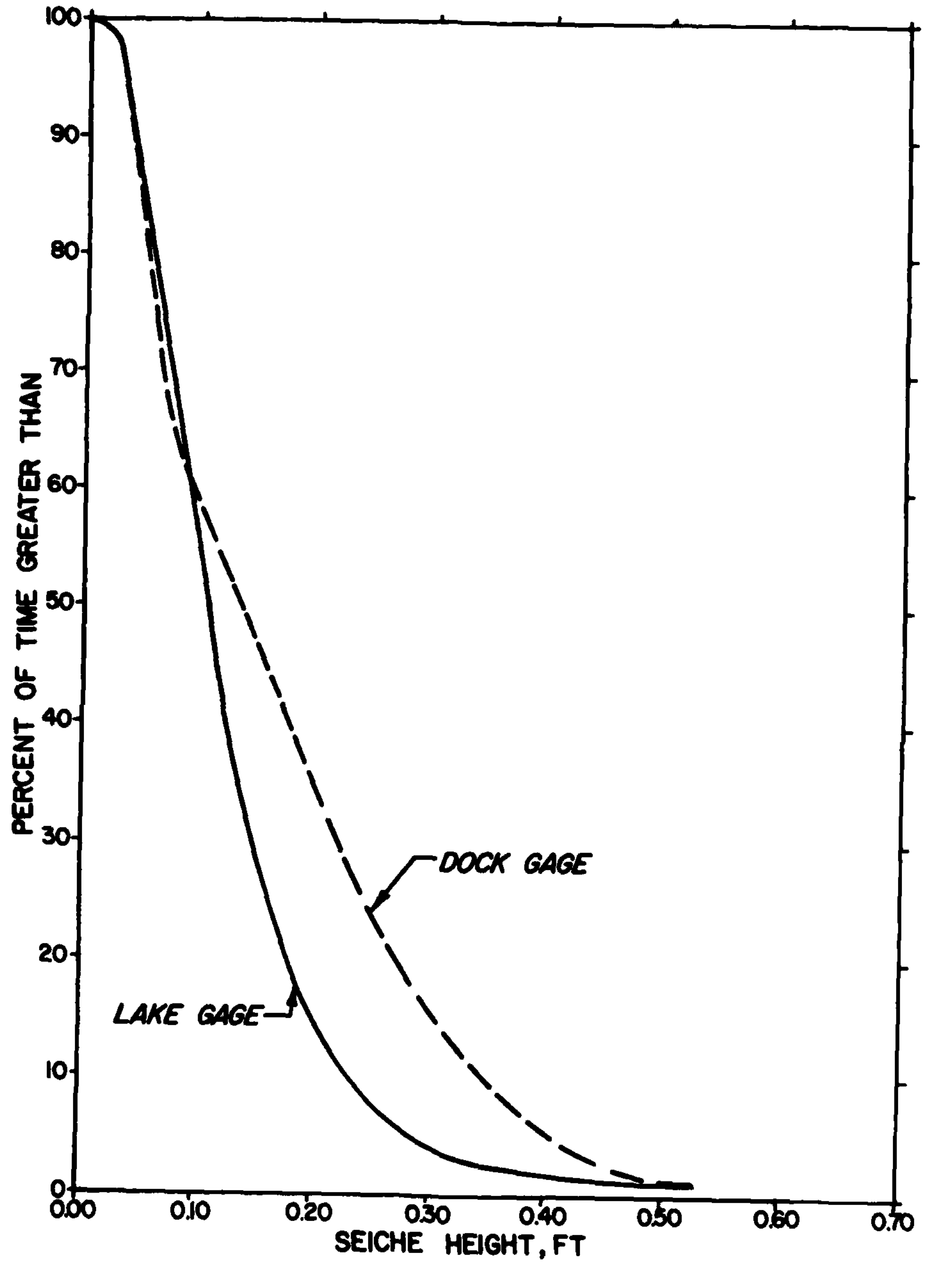


CUMULATIVE VELOCITIES

*AVERAGE VELOCITY AT MINIMUM CROSS SECTION CHANNEL.

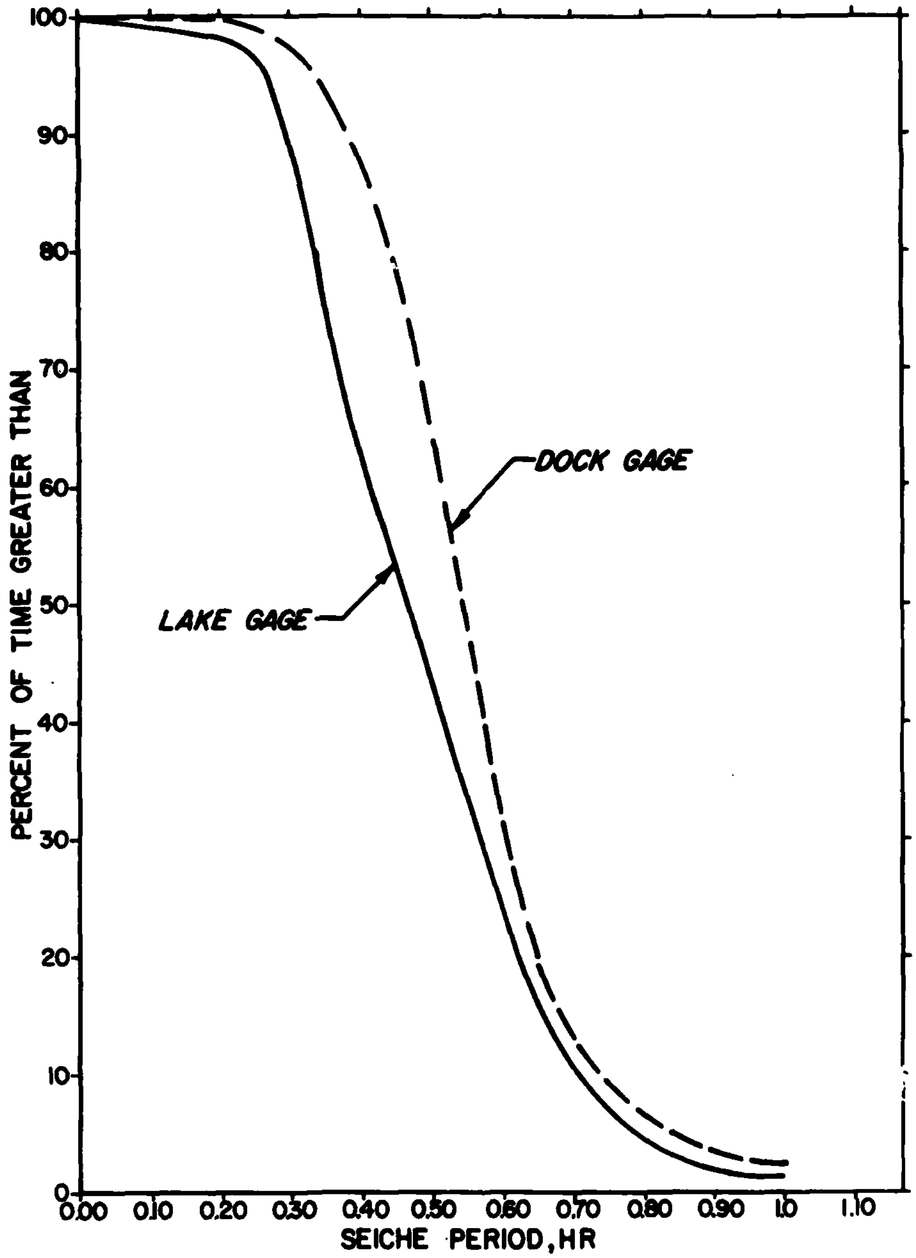
SEICHE-GENERATED
VELOCITY MAGNITUDES
24-29 SEP 1979
DATA SET 5

PLATE 13



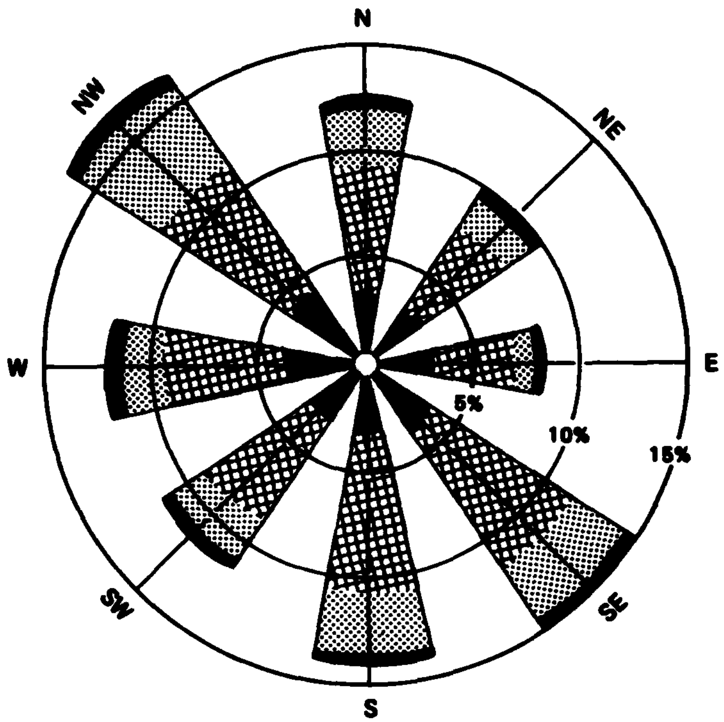
CUMULATIVE
SEICHE HEIGHTS
(ALL DATA 1979)

PLATE 14



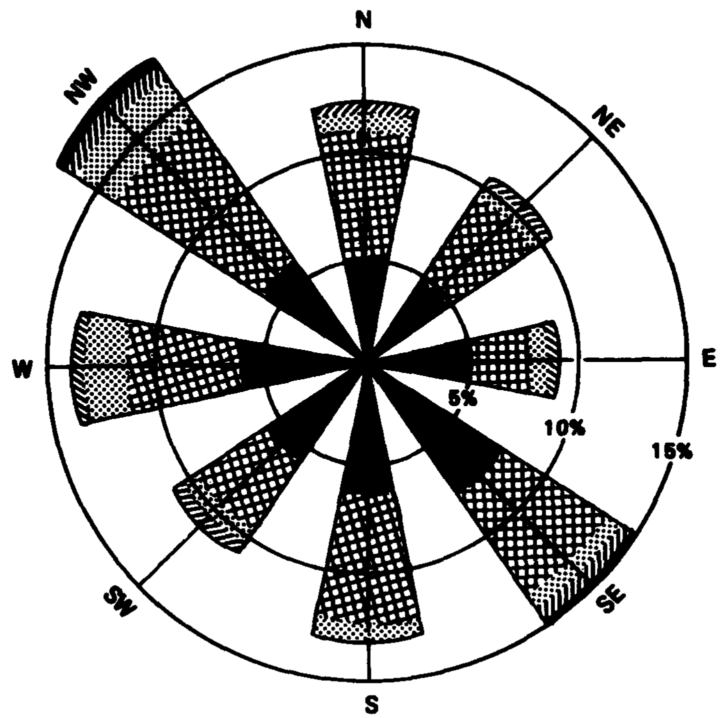
CUMULATIVE
SEICHE PERIODS
(ALL DATA 1979)

PLATE 16



WIND ROSE FOR LITTLE LAKE HARBOR
(BASED ON SSMO DATA 1960-1973)

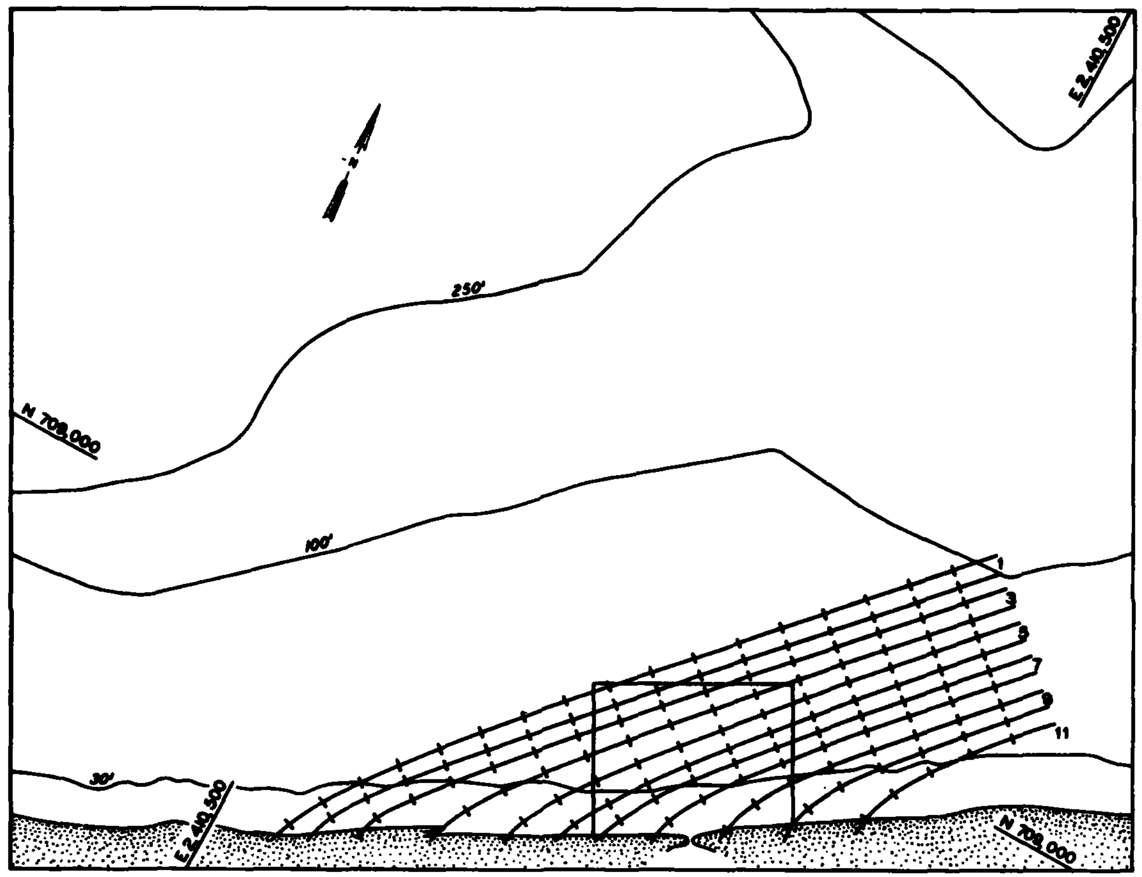
1-3 MPH
4-12 MPH
13-12 MPH
26-40 MPH
> 40 MPH



WAVE ROSE FOR LITTLE LAKE HARBOR
(BASED ON SSMO DATA 1960-1973)

0-2 FEET
3-6 FEET
7-9 FEET
10-12 FEET
> 12 FEET

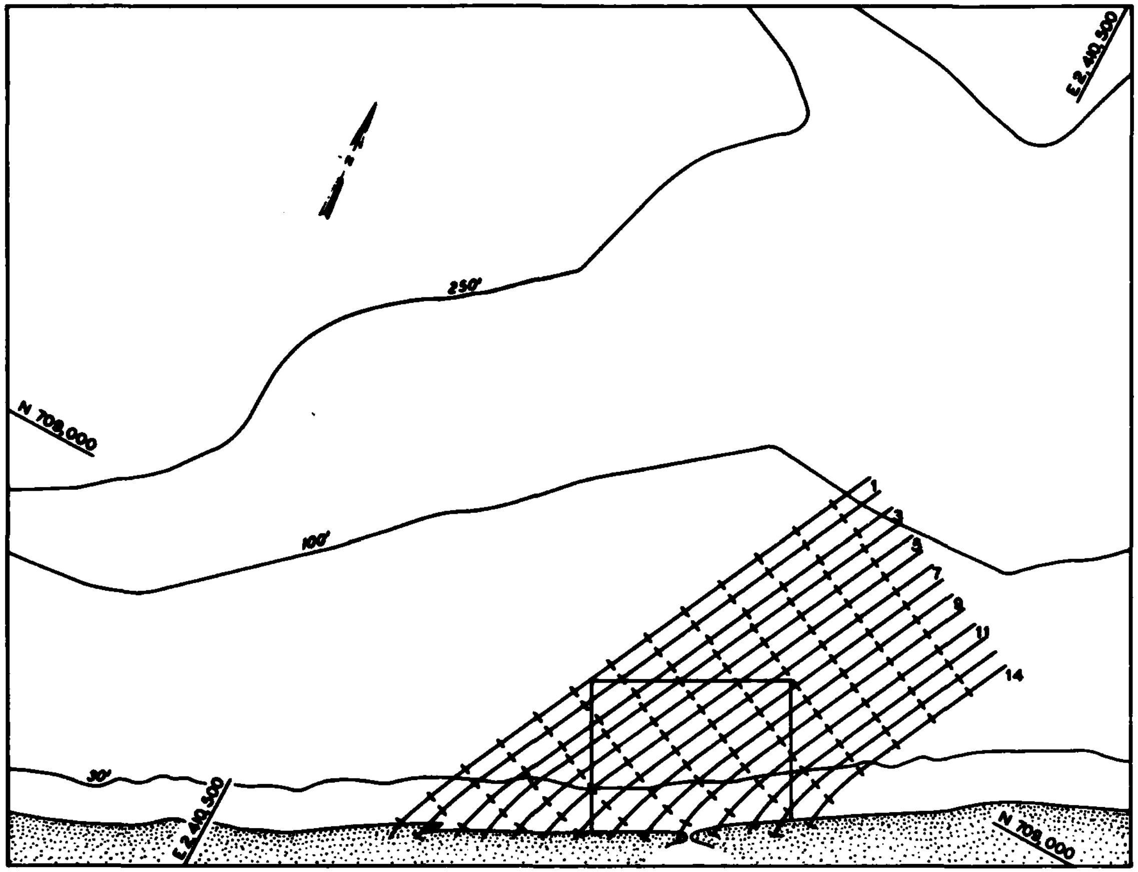
WIND AND WAVE ROSES
FOR LITTLE LAKE HARBOR



WAVE REFRACTION

WAVE PERIOD	5.000 SECONDS
DEEPWATER DIRECTION	46.5 DEGREES

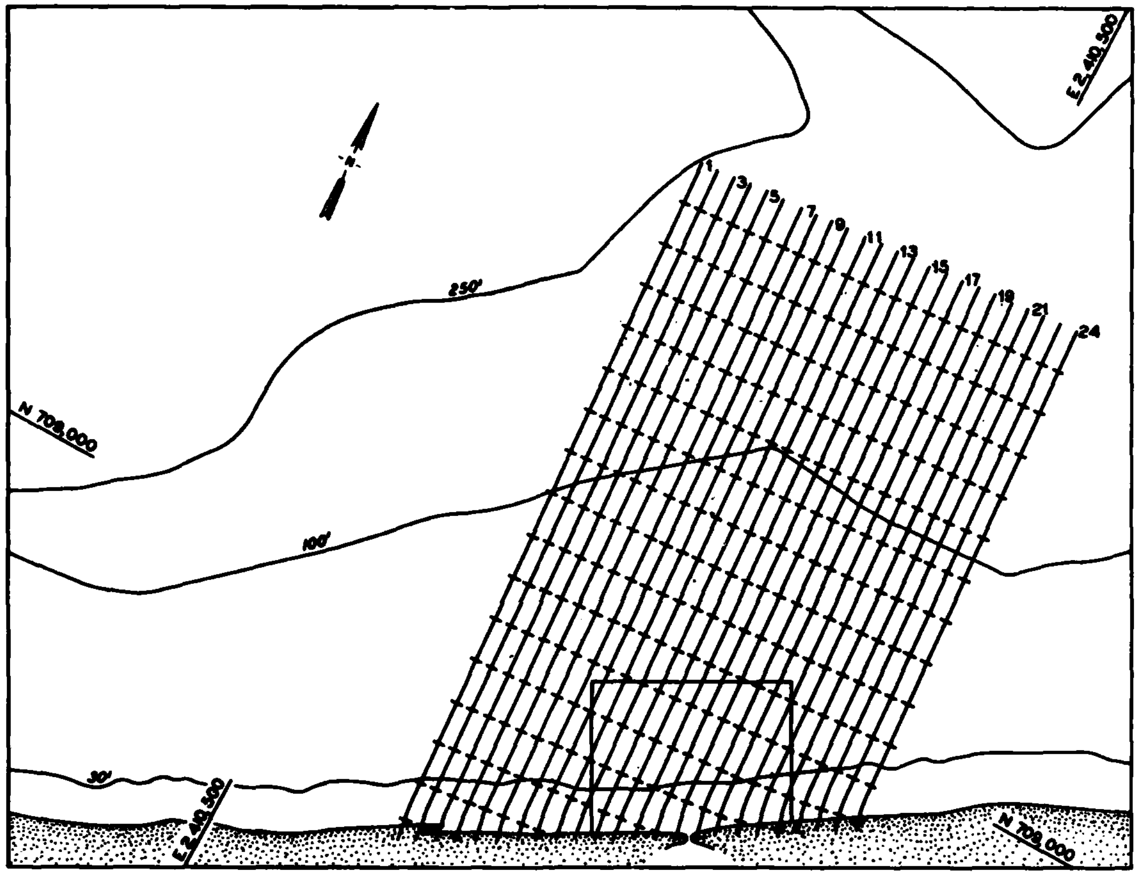
PLATE 17



WAVE REFRACTION

WAVE PERIOD	5.000 SECONDS
DEEPWATER DIRECTION	30.0 DEGREES

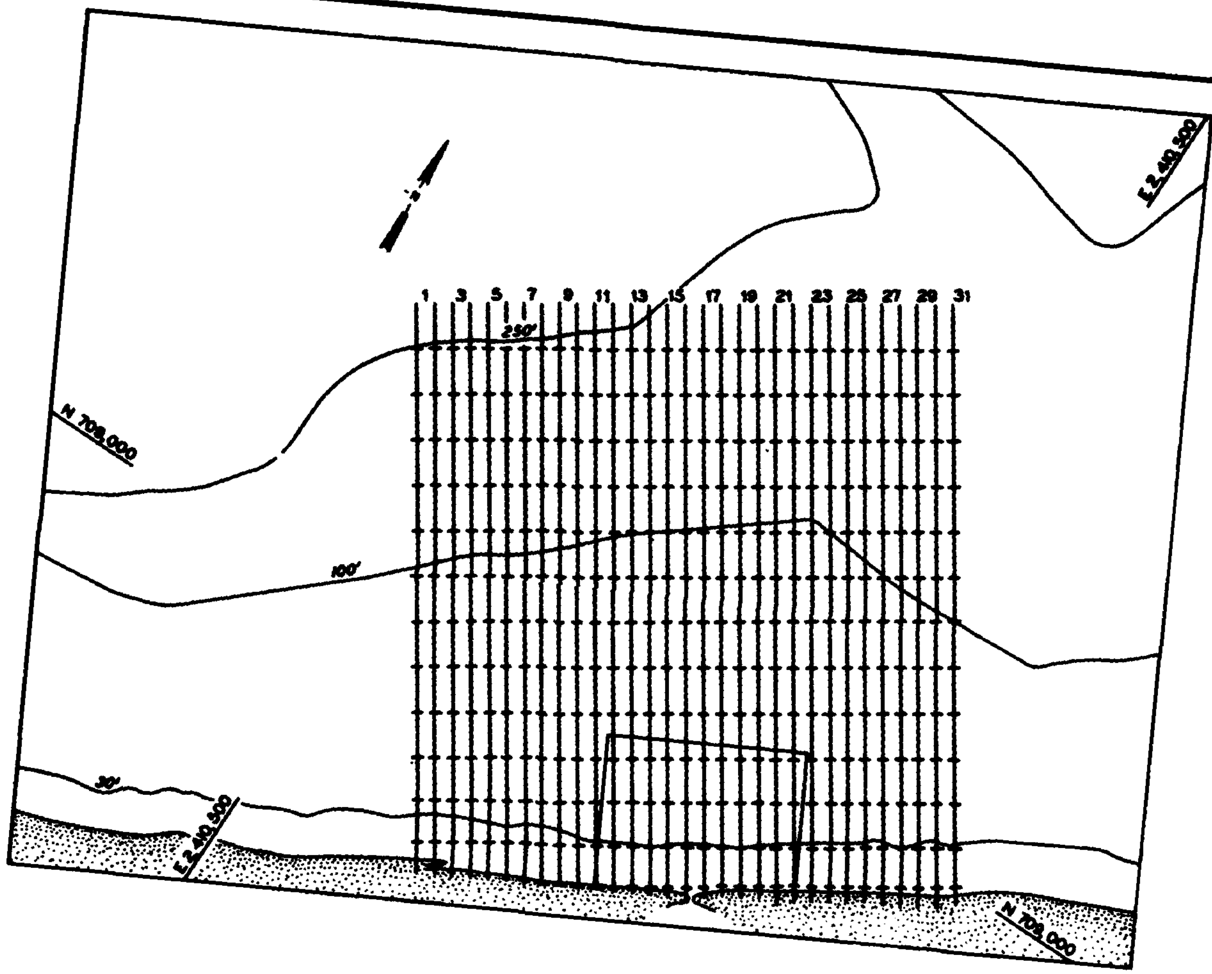
PLATE 18



WAVE REFRACTION

WAVE PERIOD 5.000 SECONDS
DEEPWATER DIRECTION 0.0 DEGREES

PLATE 19

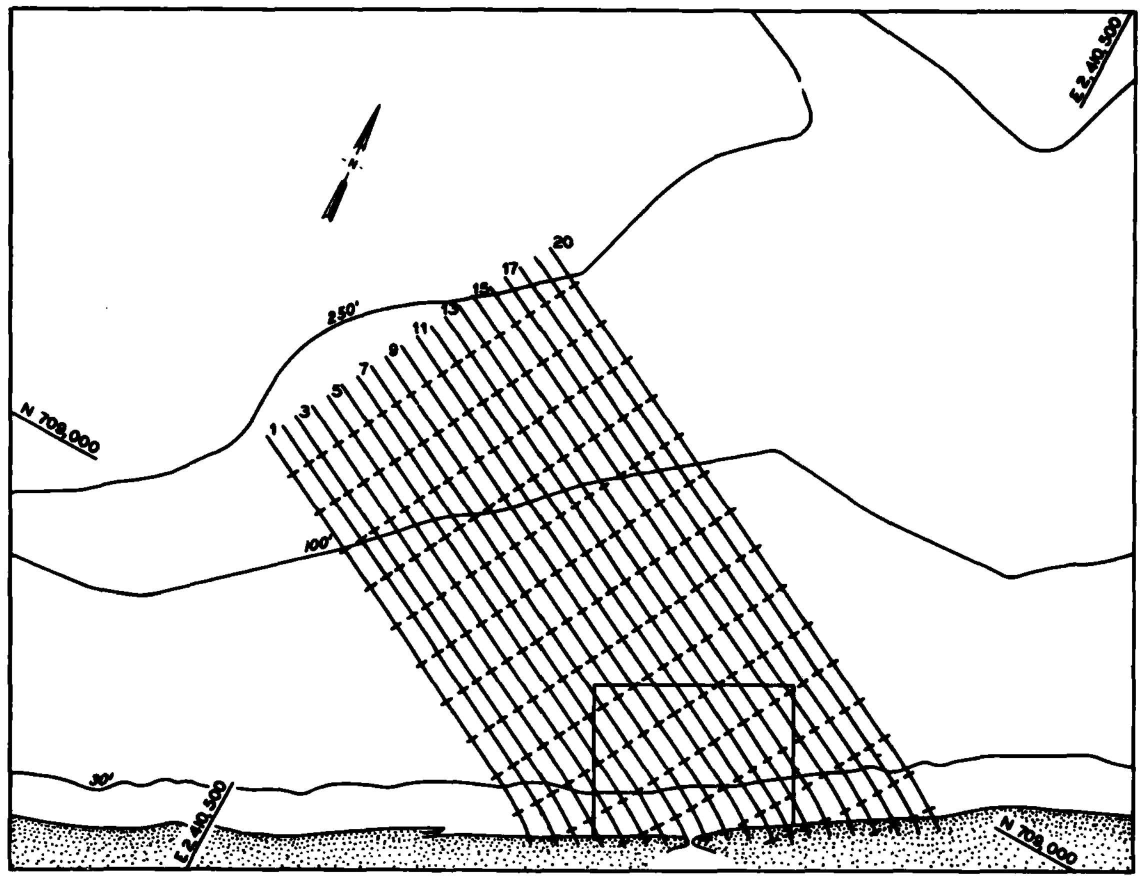


WAVE REFRACTION

WAVE PERIOD 5.000 SECONDS

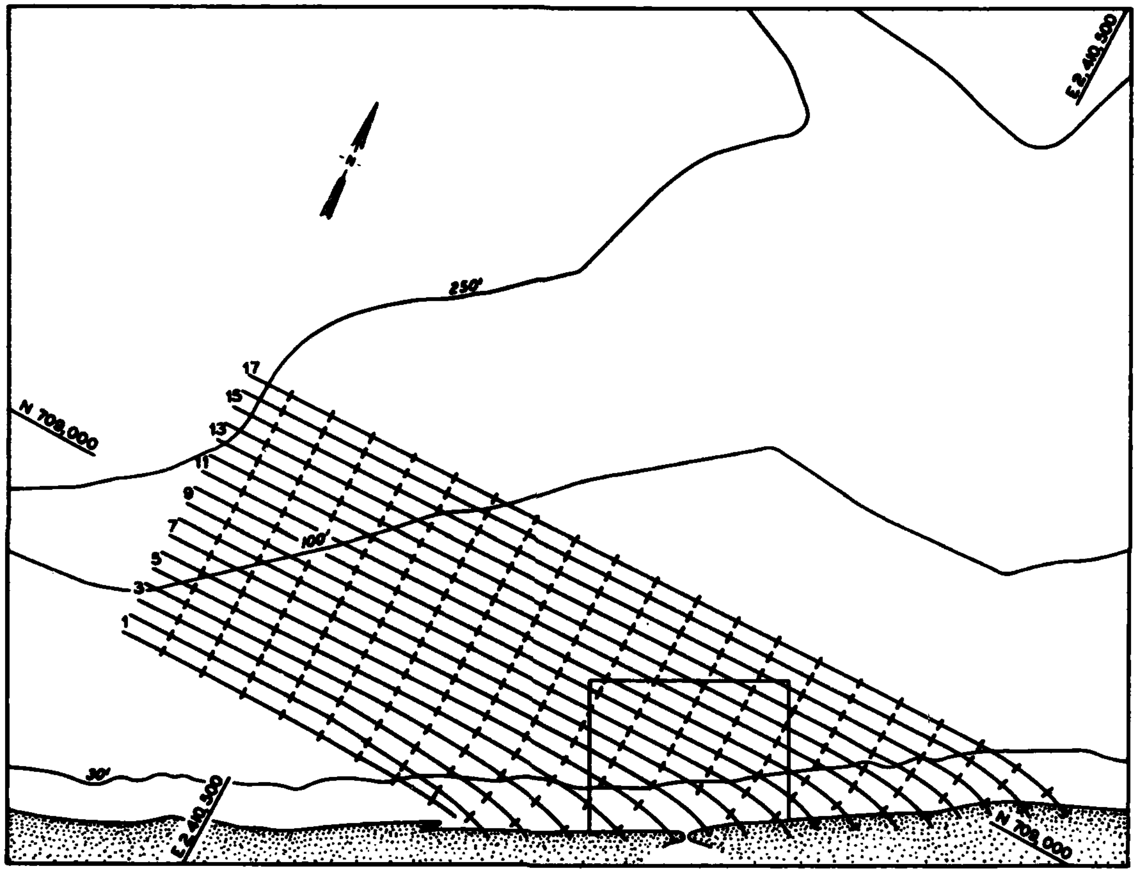
DEEPWATER DIRECTION 330.0 DEGREES

PLATE 20



WAVE REFRACTION

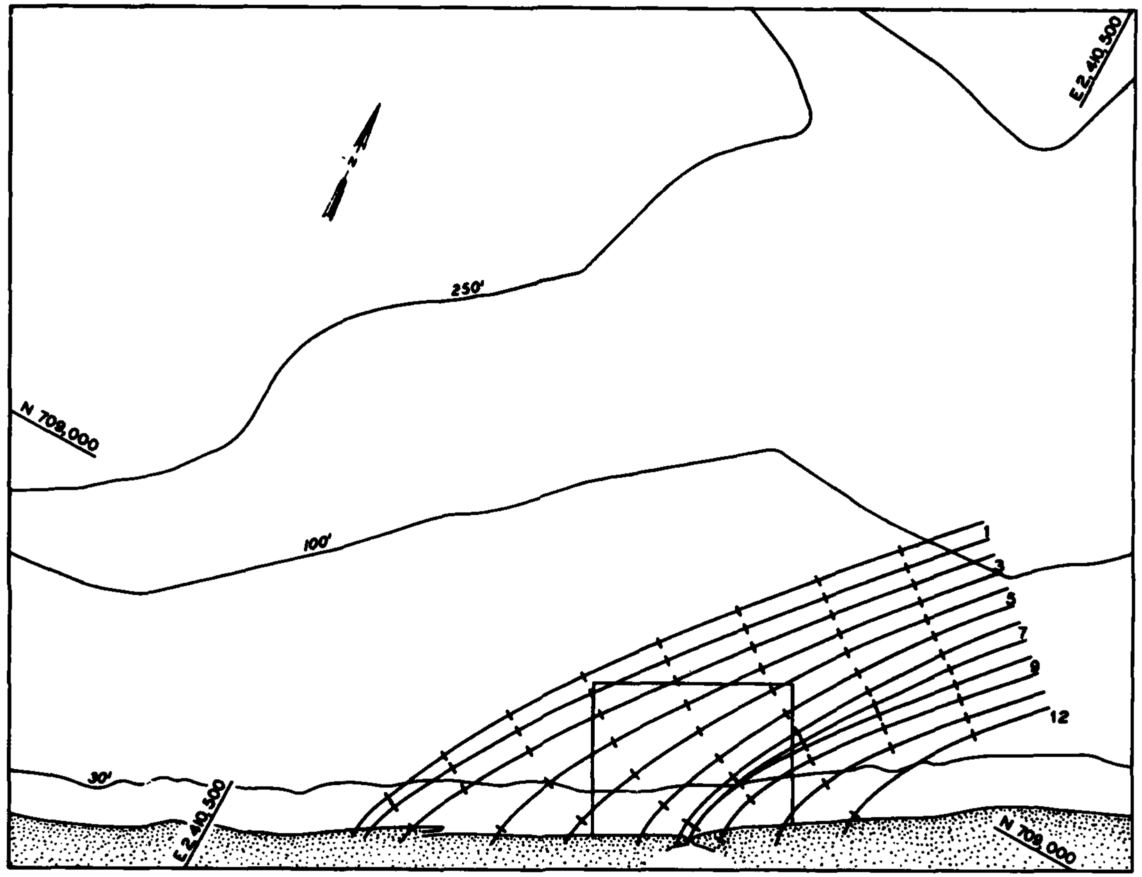
WAVE PERIOD	5.000 SECONDS
DEEPWATER DIRECTION	301.0 DEGREES



WAVE REFRACTION

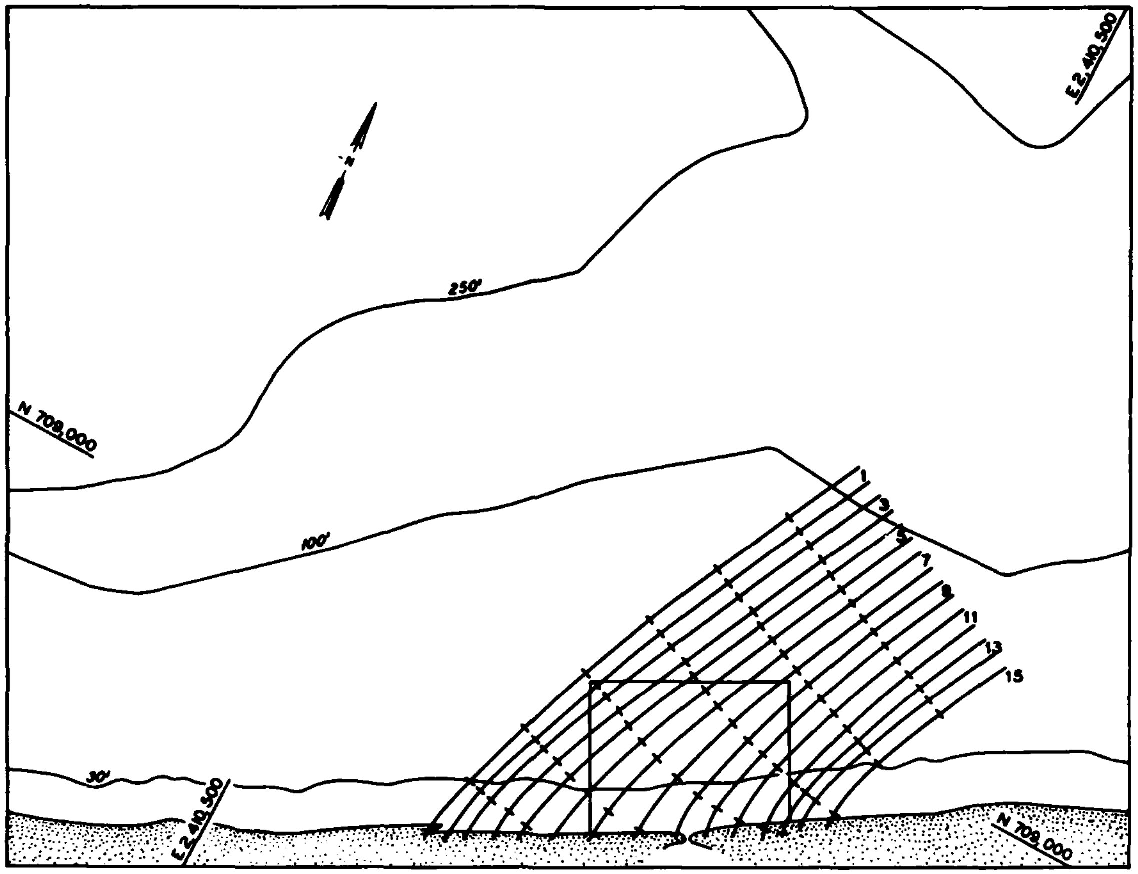
WAVE PERIOD	5.000 SECONDS
DEEPWATER DIRECTION	272.0 DEGREES

PLATE 22



WAVE REFRACTION

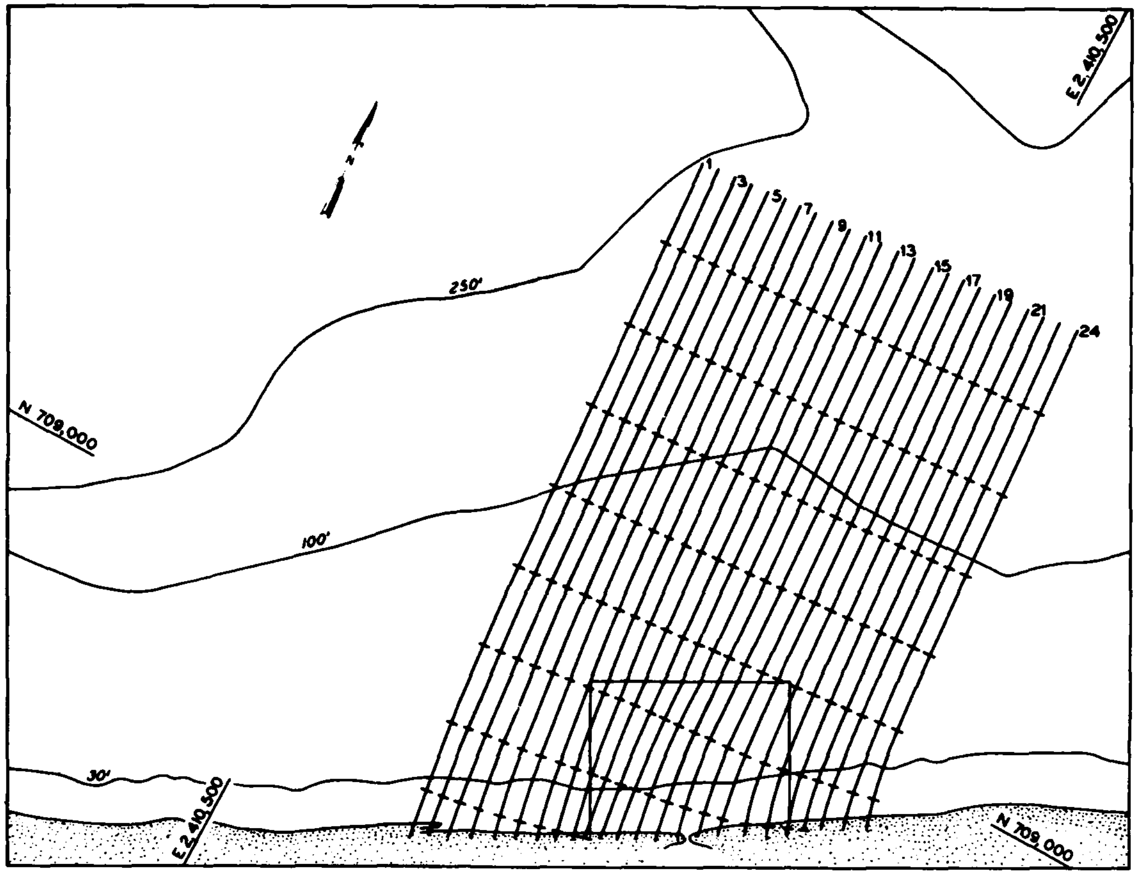
WAVE PERIOD 7.000 SECONDS
DEEPWATER DIRECTION 46.5 DEGREES



WAVE REFRACTION

WAVE PERIOD 7.000 SECONDS
DEEPWATER DIRECTION 30.0 DEGREES

PLATE 24



WAVE REFRACTION

WAVE PERIOD	7.000 SECONDS
DEEPWATER DIRECTION	0.0 DEGREES

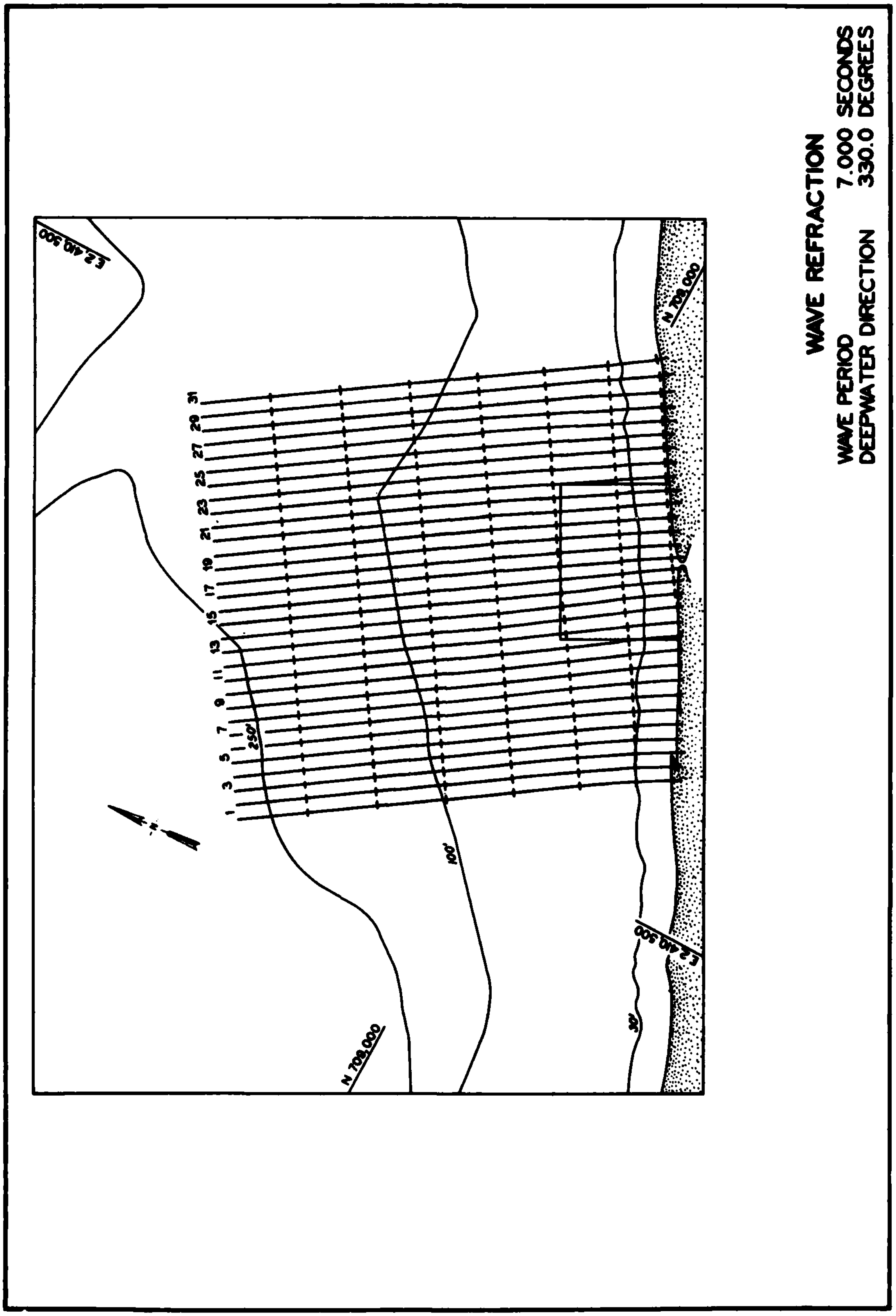
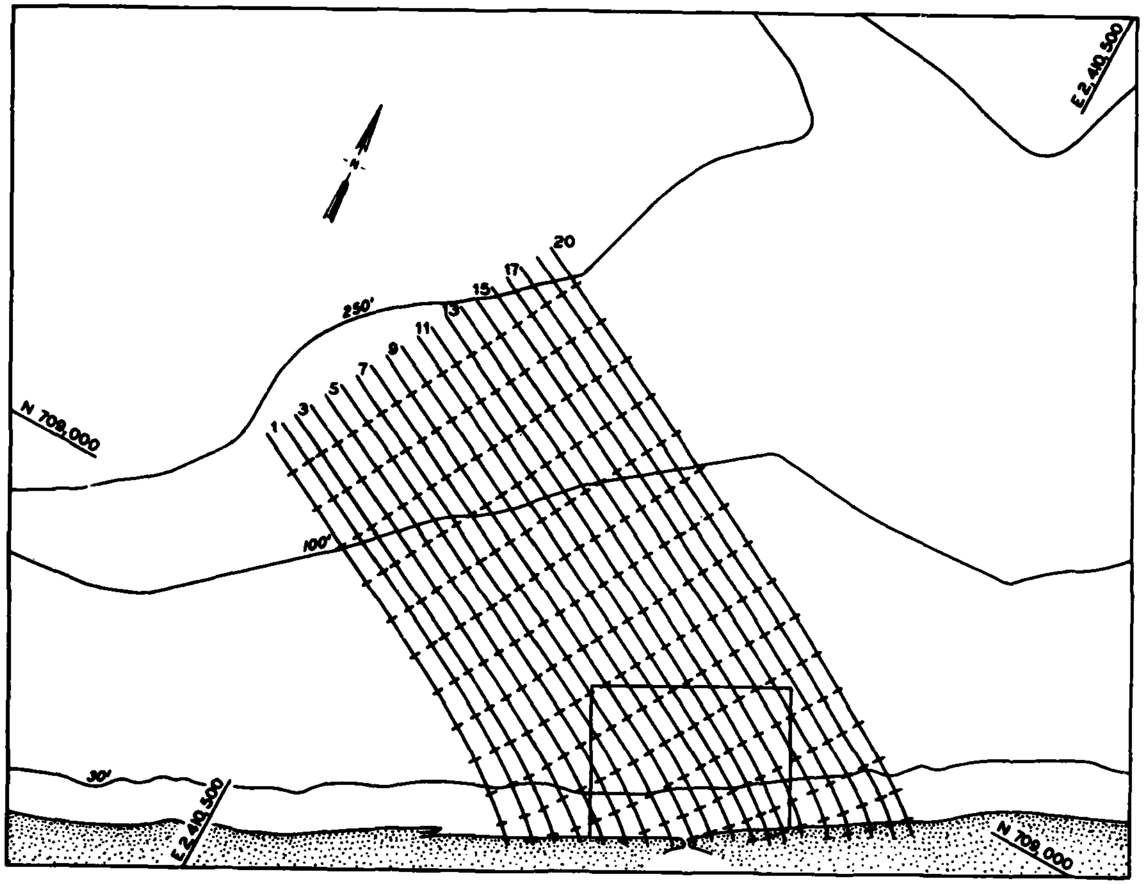

WAVE REFRACTION
WAVE PERIOD 7.000 SECONDS
DEEPWATER DIRECTION 330.0 DEGREES
N 709,000
N 708,000
E 2,410,500
E 2,410,500
250'
100'
30'
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31

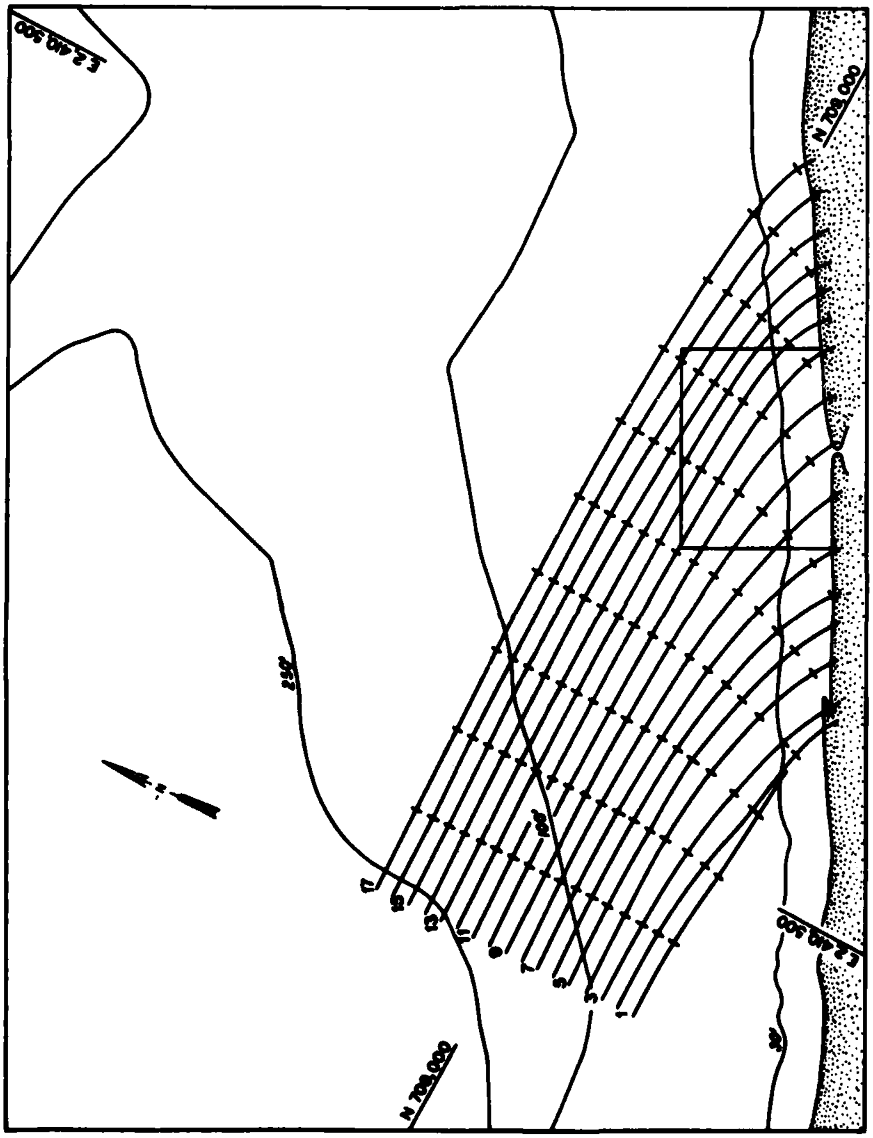
PLATE 26



WAVE REFRACTION

WAVE PERIOD 7.000 SECONDS
DEEPWATER DIRECTION 301.0 DEGREES

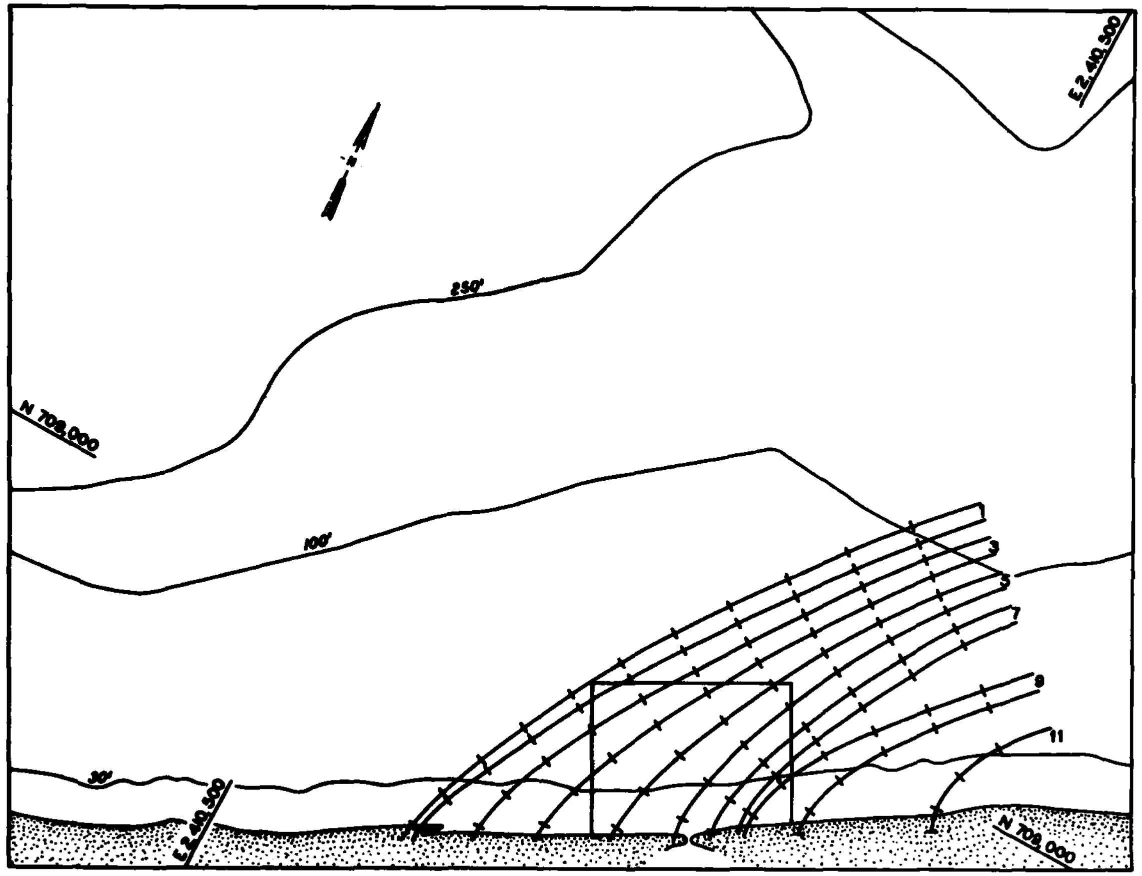
PLATE 27



WAVE REFRACTION

WAVE PERIOD 7.000 SECONDS
DEEPWATER DIRECTION 272.0 DEGREES

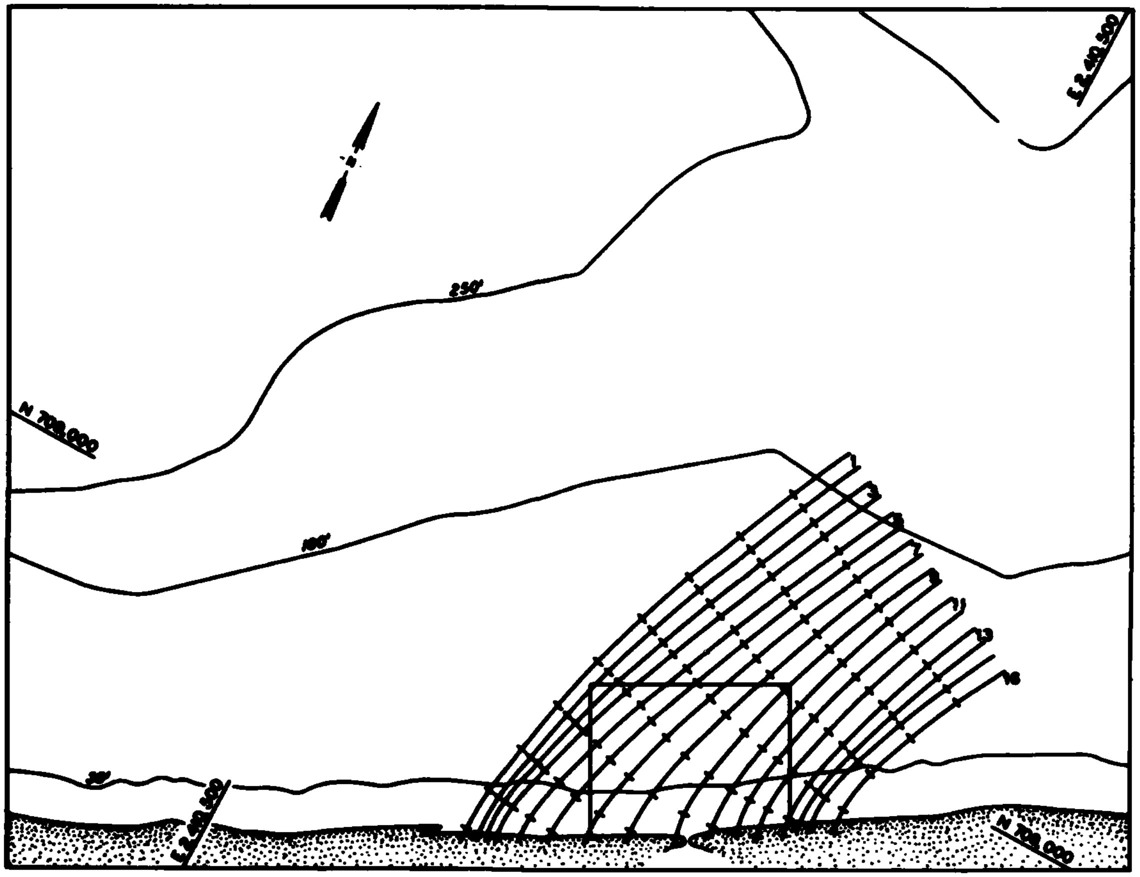
PLATE 28



WAVE REFRACTION

WAVE PERIOD	9.000 SECONDS
DEEPWATER DIRECTION	46.5 DEGREES

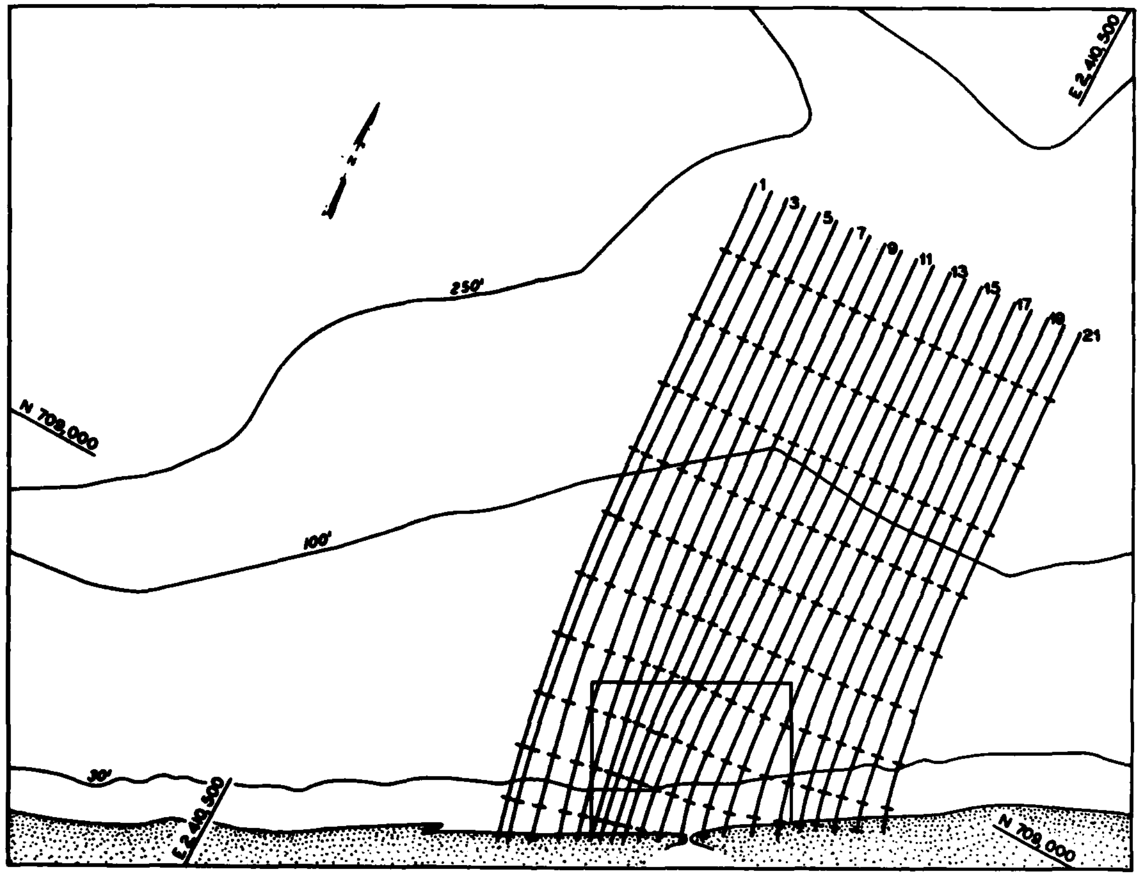
PLATE 29



WAVE REFRACTION

WAVE PERIOD	9.000 SECONDS
DEEPWATER DIRECTION	30.0 DEGREES

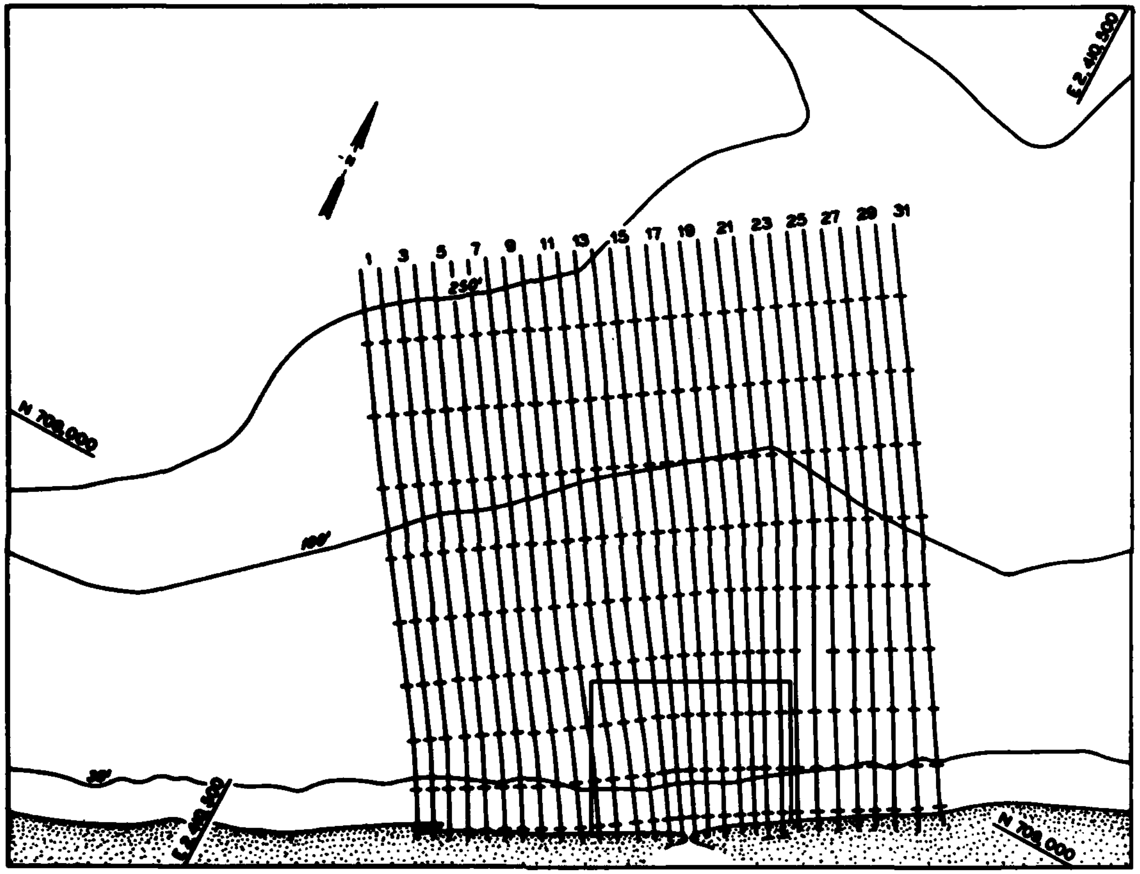
PLATE 30



WAVE REFRACTION

WAVE PERIOD 9.000 SECONDS
DEEPWATER DIRECTION 0.0 DEGREES

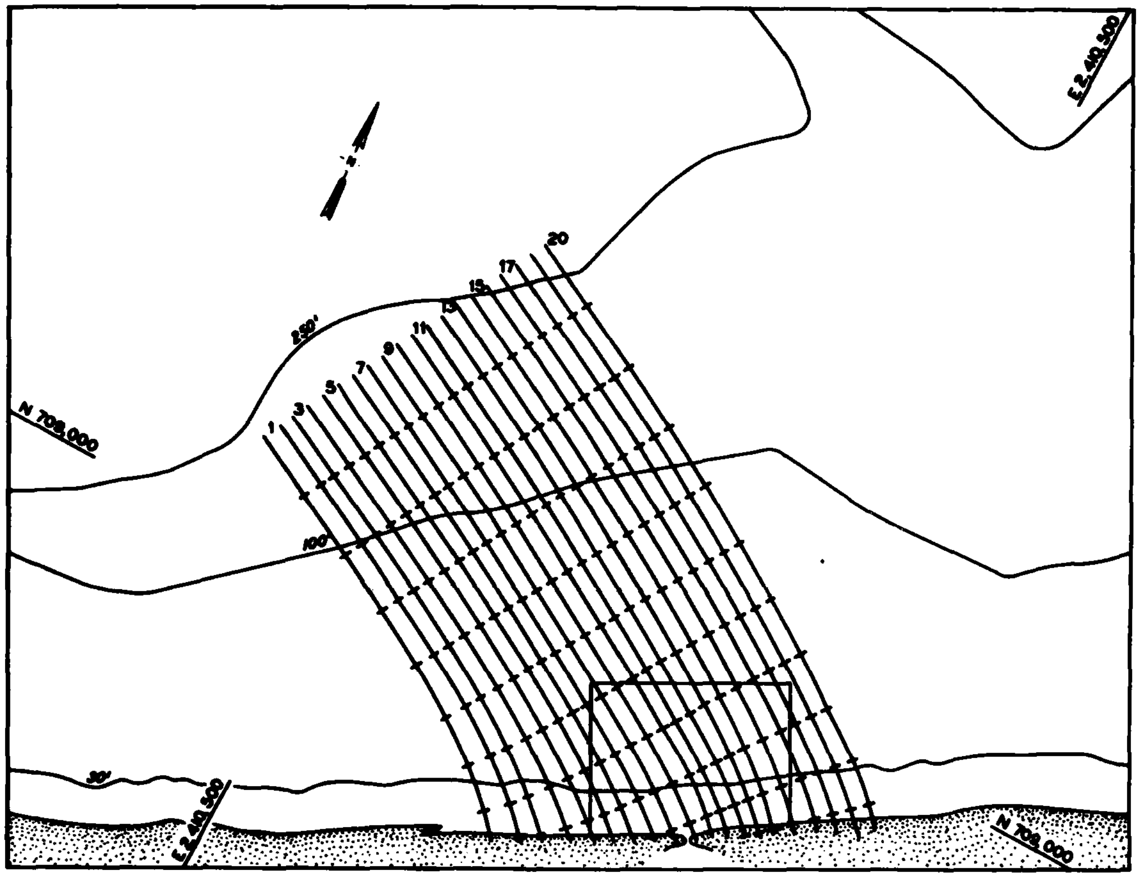
PLATE 31



WAVE REFRACTION

WAVE PERIOD 9.000 SECONDS
DEEPWATER DIRECTION 330.0 DEGREES

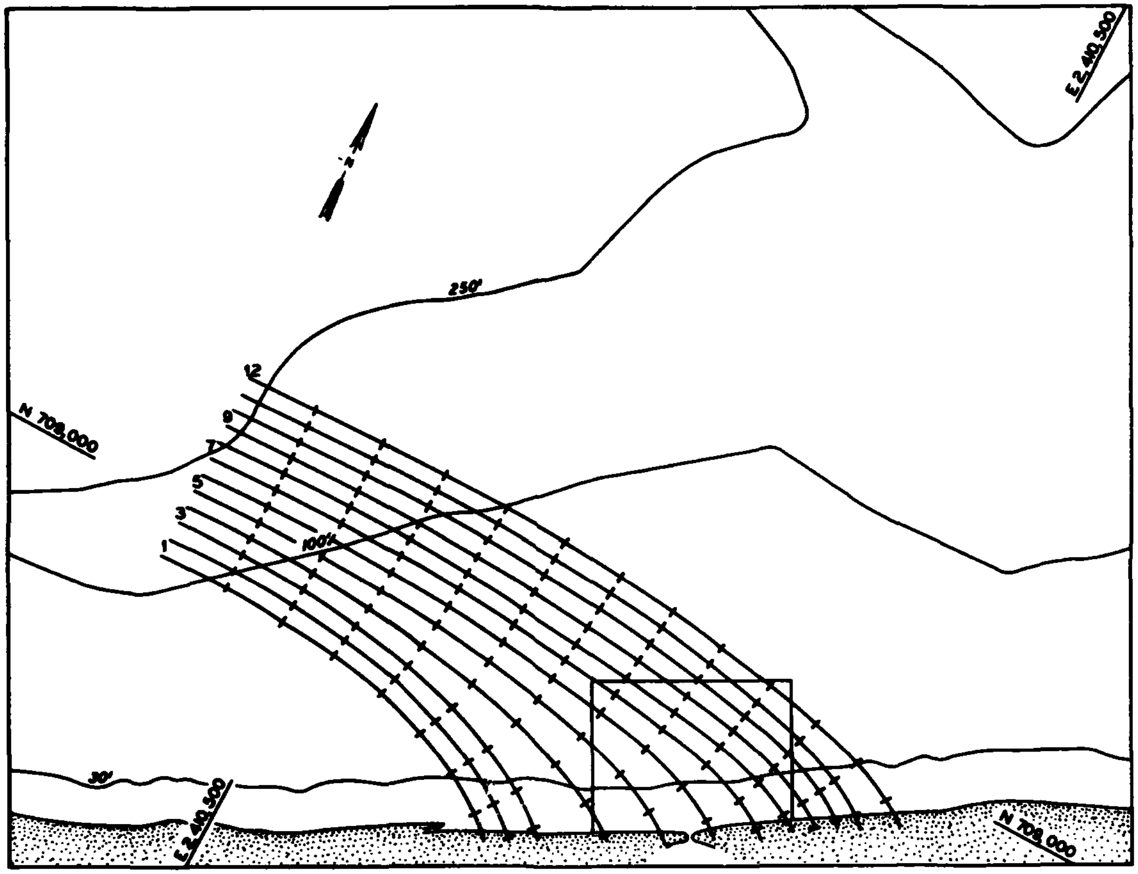
PLATE 32



WAVE REFRACTION

WAVE PERIOD 9.000 SECONDS
DEEPWATER DIRECTION 301.0 DEGREES

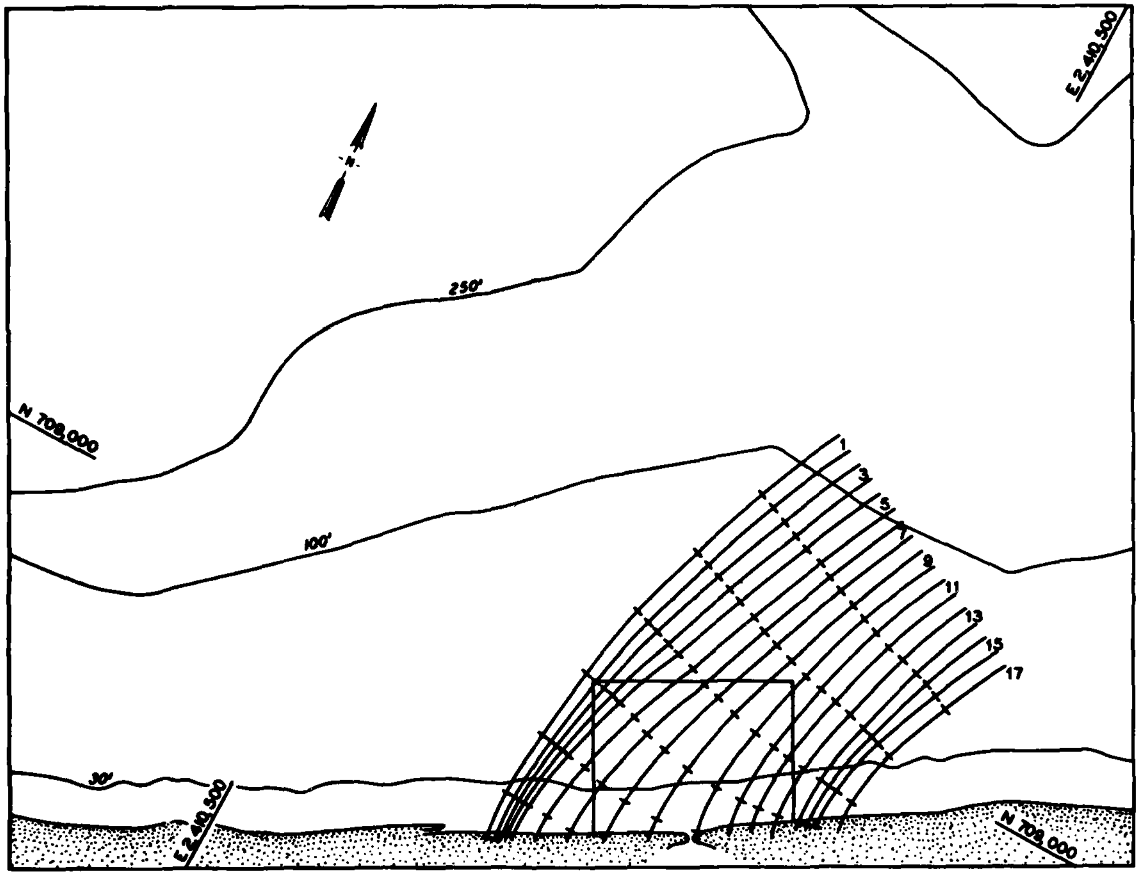
PLATE 33



WAVE REFRACTION

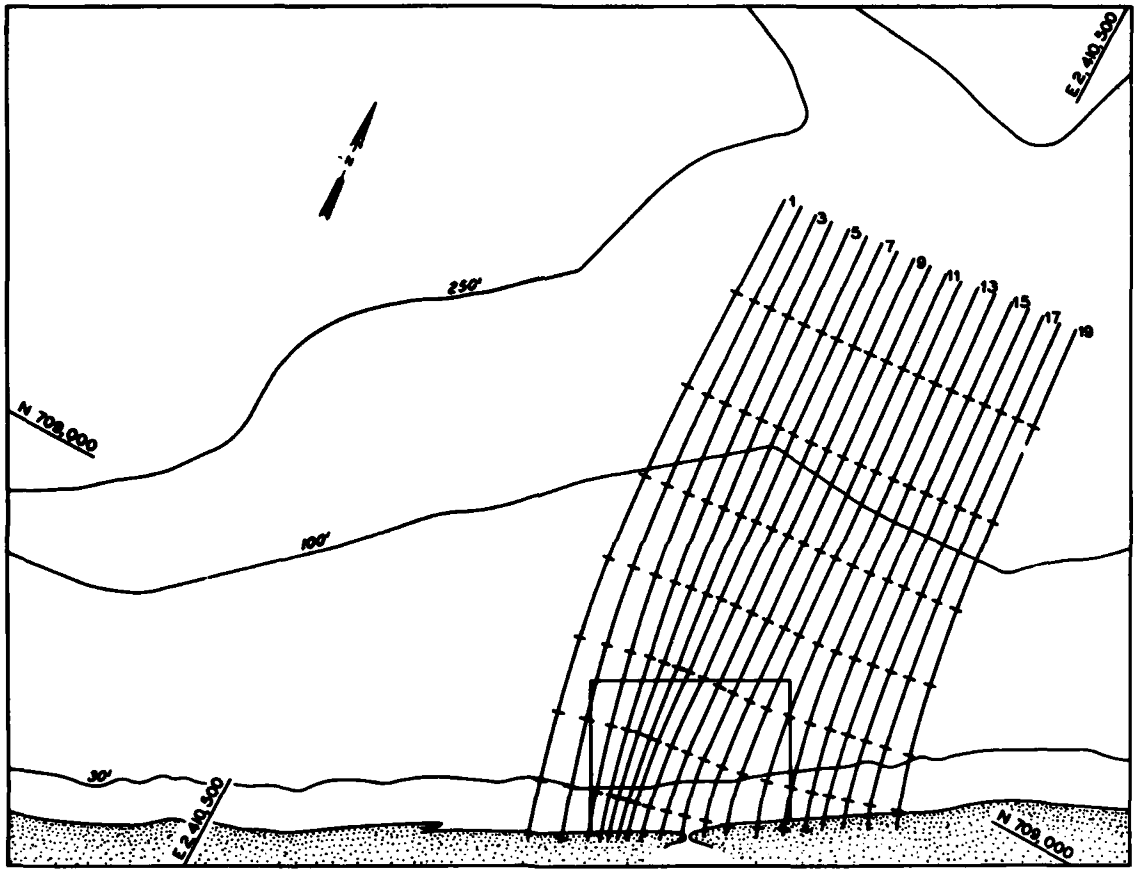
WAVE PERIOD 9.000 SECONDS
DEEPWATER DIRECTION 272.0 DEGREES

PLATE 34



WAVE REFRACTION

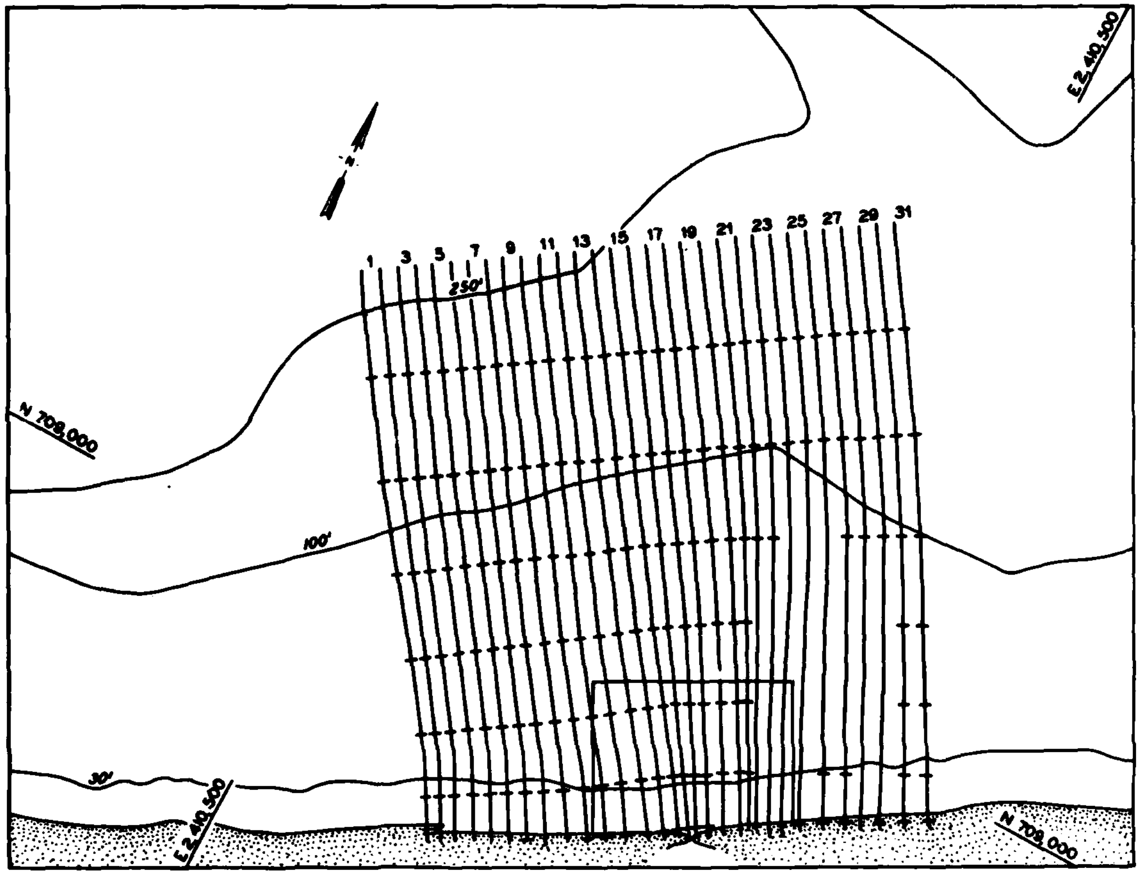
WAVE PERIOD 11.000 SECONDS
DEEPWATER DIRECTION 30.0 DEGREES



WAVE REFRACTION

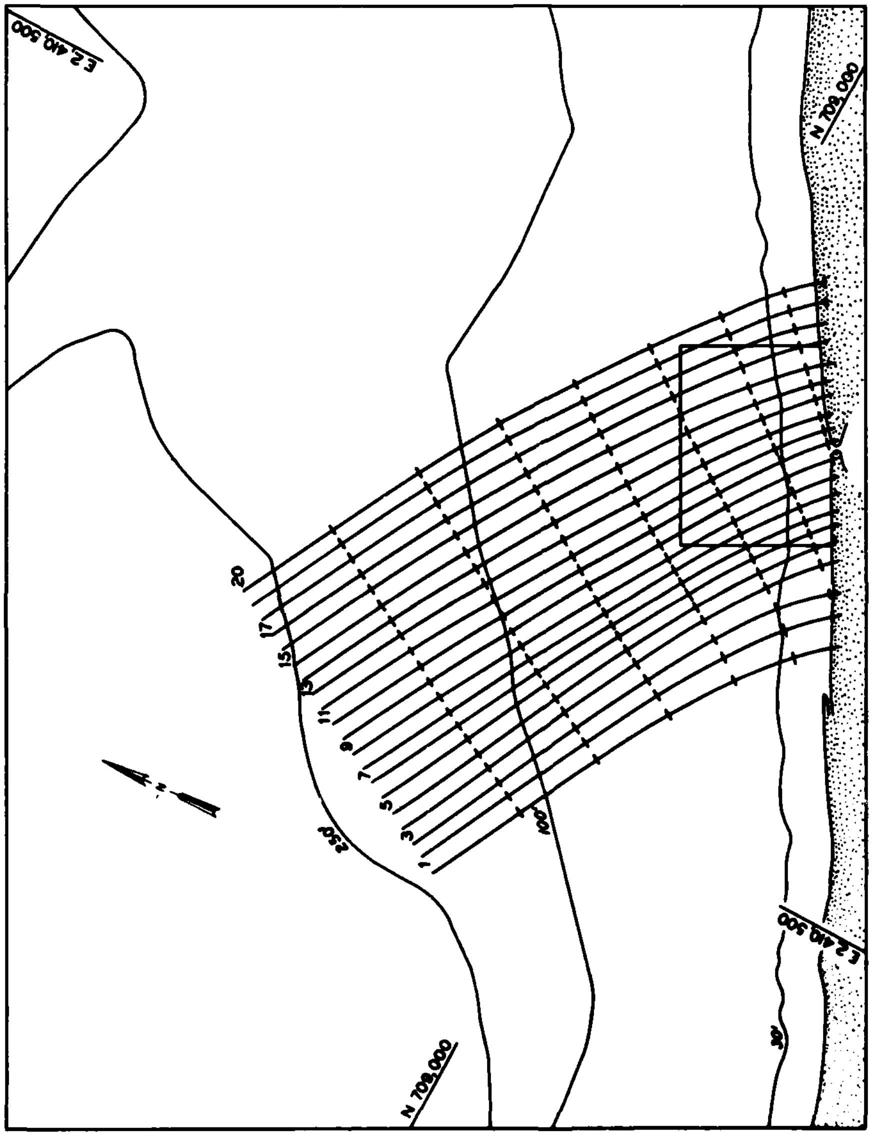
WAVE PERIOD 11.000 SECONDS
DEEPWATER DIRECTION 0.0 DEGREES

PLATE 36



WAVE REFRACTION

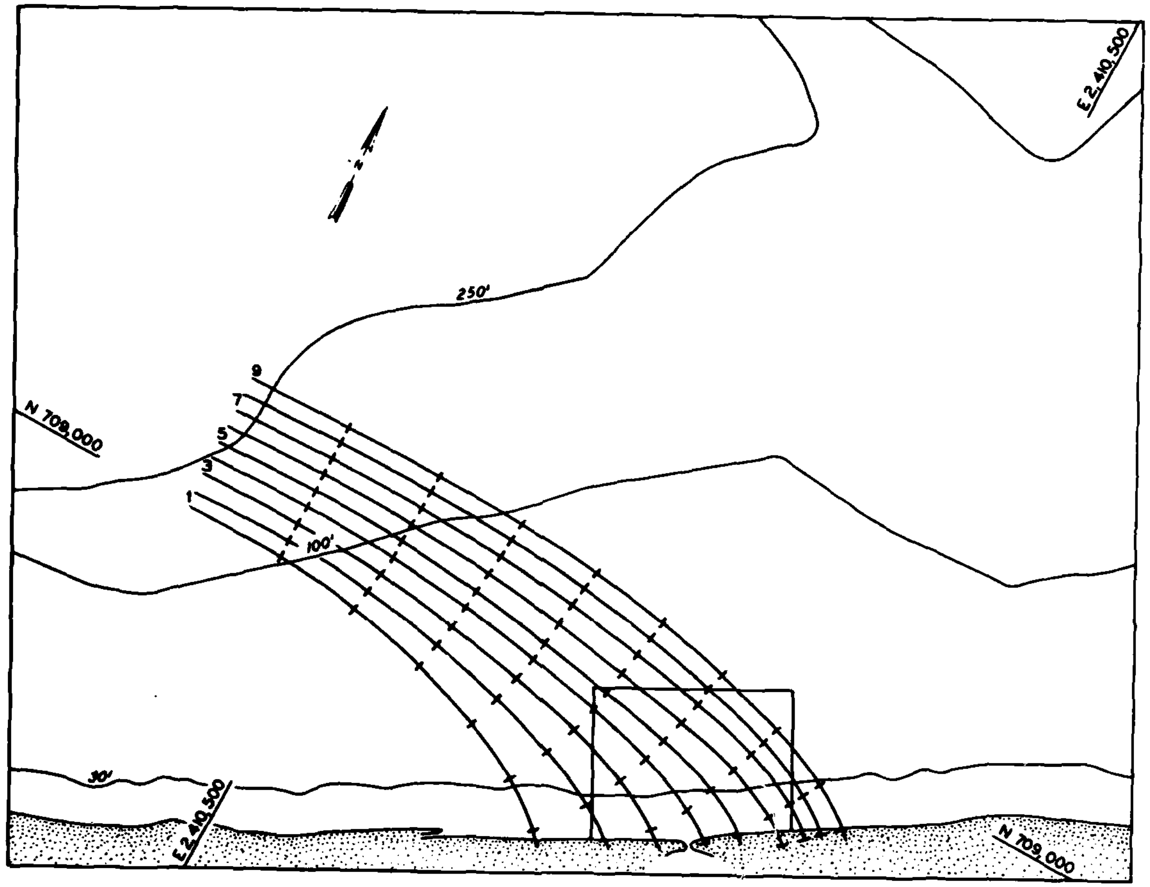
WAVE PERIOD 11.000 SECONDS
DEEPWATER DIRECTION 330.0 DEGREES



WAVE REFRACTION

WAVE PERIOD 11.000 SECONDS
DEEPWATER DIRECTION 301.0 DEGREES

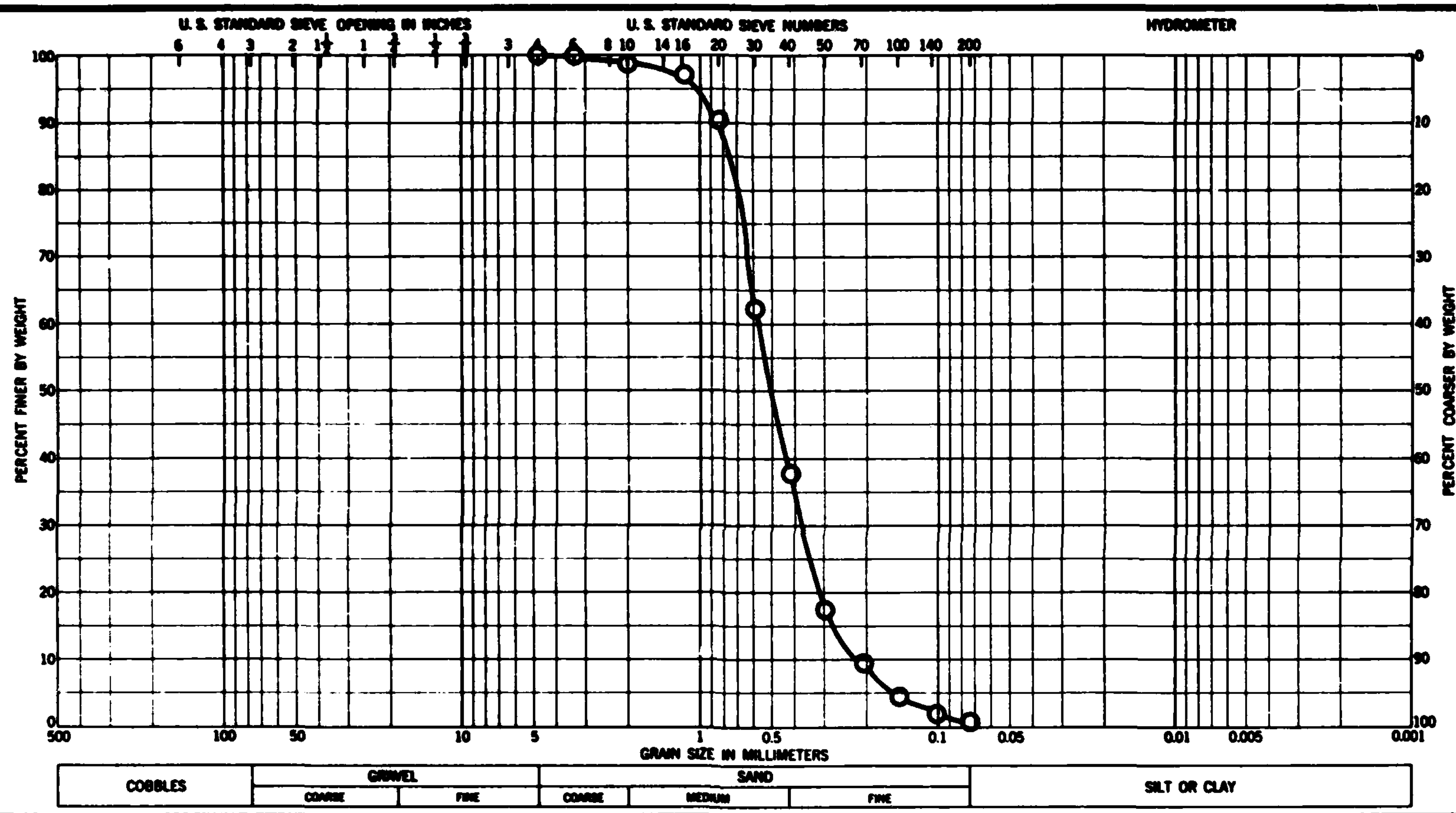
PLATE 38



WAVE REFRACTION

WAVE PERIOD	11.000 SECONDS
DEEPWATER DIRECTION	272.0 DEGREES

PLATE 39



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2		BLACK (COAL)				
		Gs = 1, 36				

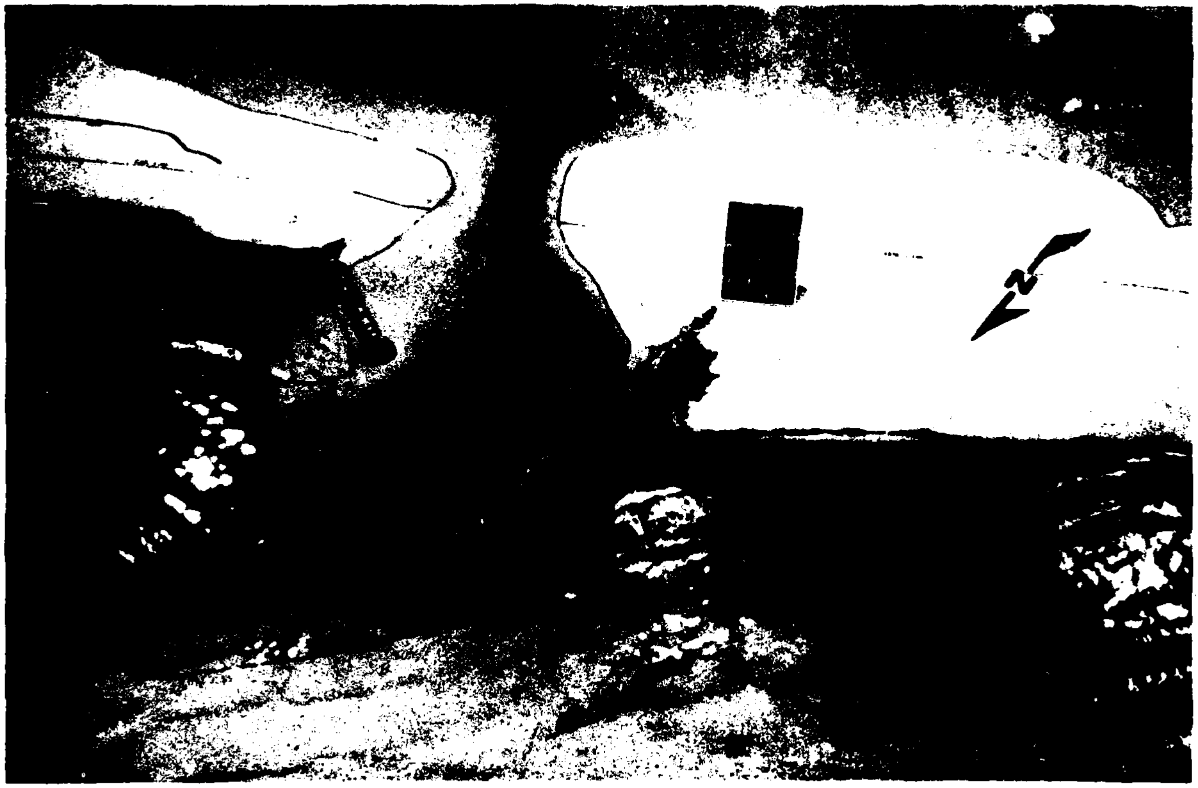
GRADATION CURVES

LITTLE LAKE HARBOR

GRADATION CURVE FOR SEDIMENT TRACER

2 FEB 78

ENG FORM 1 MAY 63 2087



CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 7 sec
WAVE HEIGHT 6.5 ft
SEICHE HEIGHT 0

SHOALING TEST I

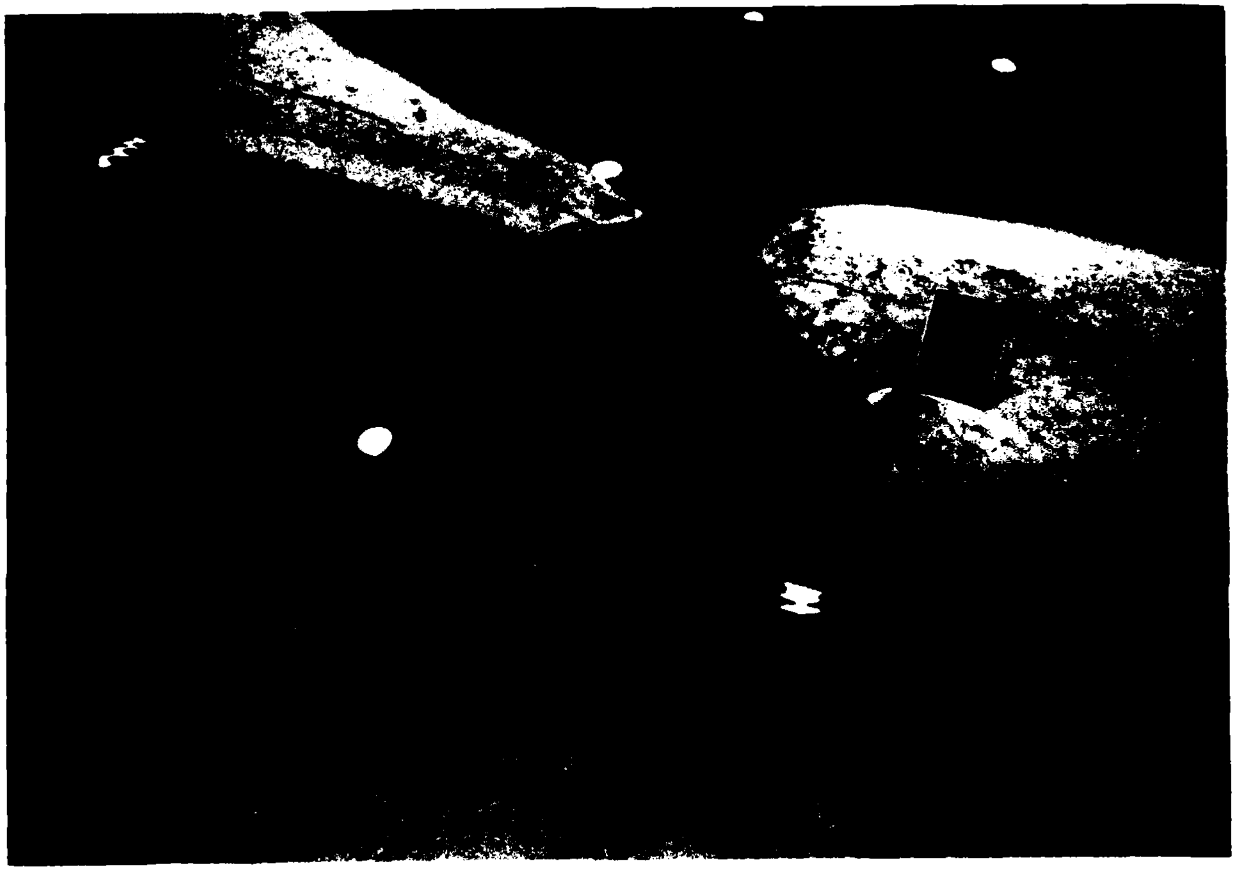
CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 7 sec
WAVE HEIGHT 6.5 ft
SEICHE HEIGHT 0

SHOALING TEST 2

PLATE 42

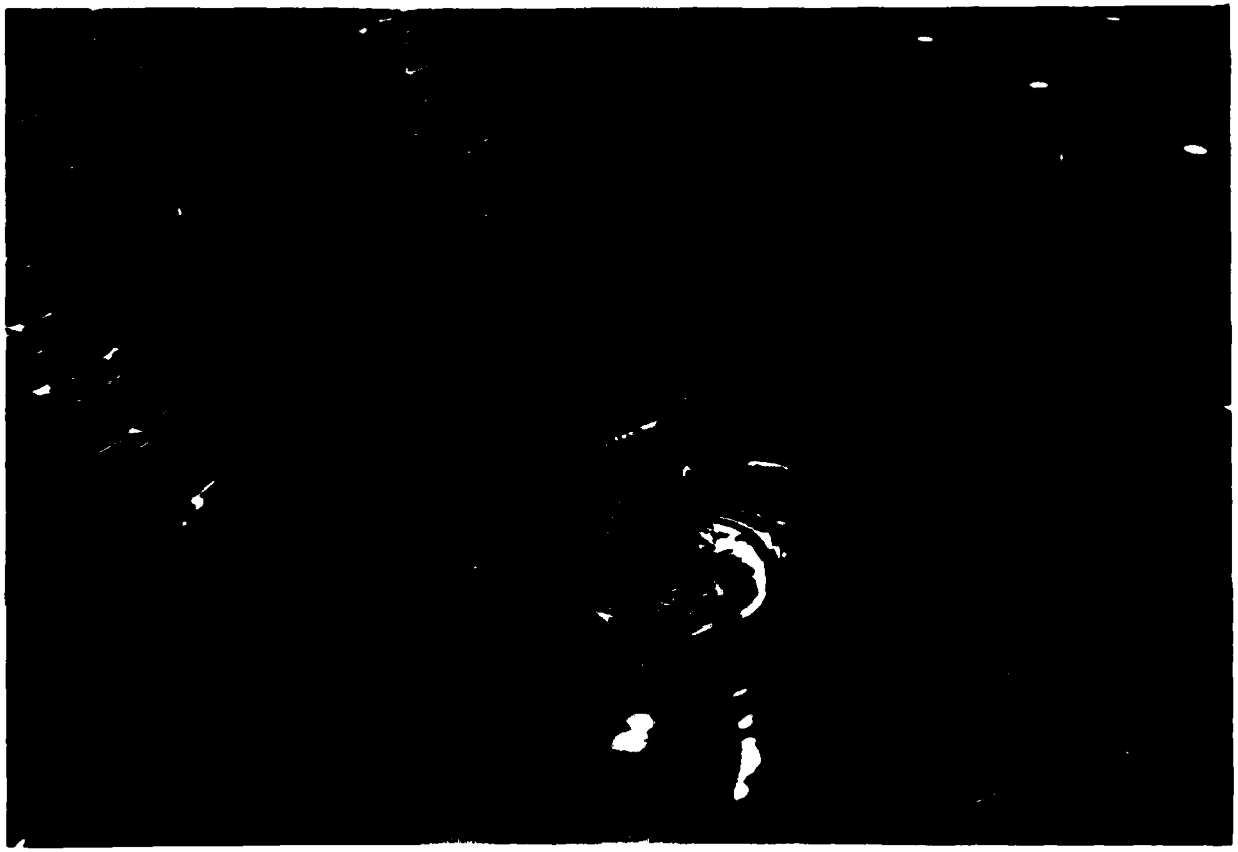
CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 7 sec
WAVE HEIGHT 4.5 ft
SEICHE HEIGHT 0

SHOALING TEST 3



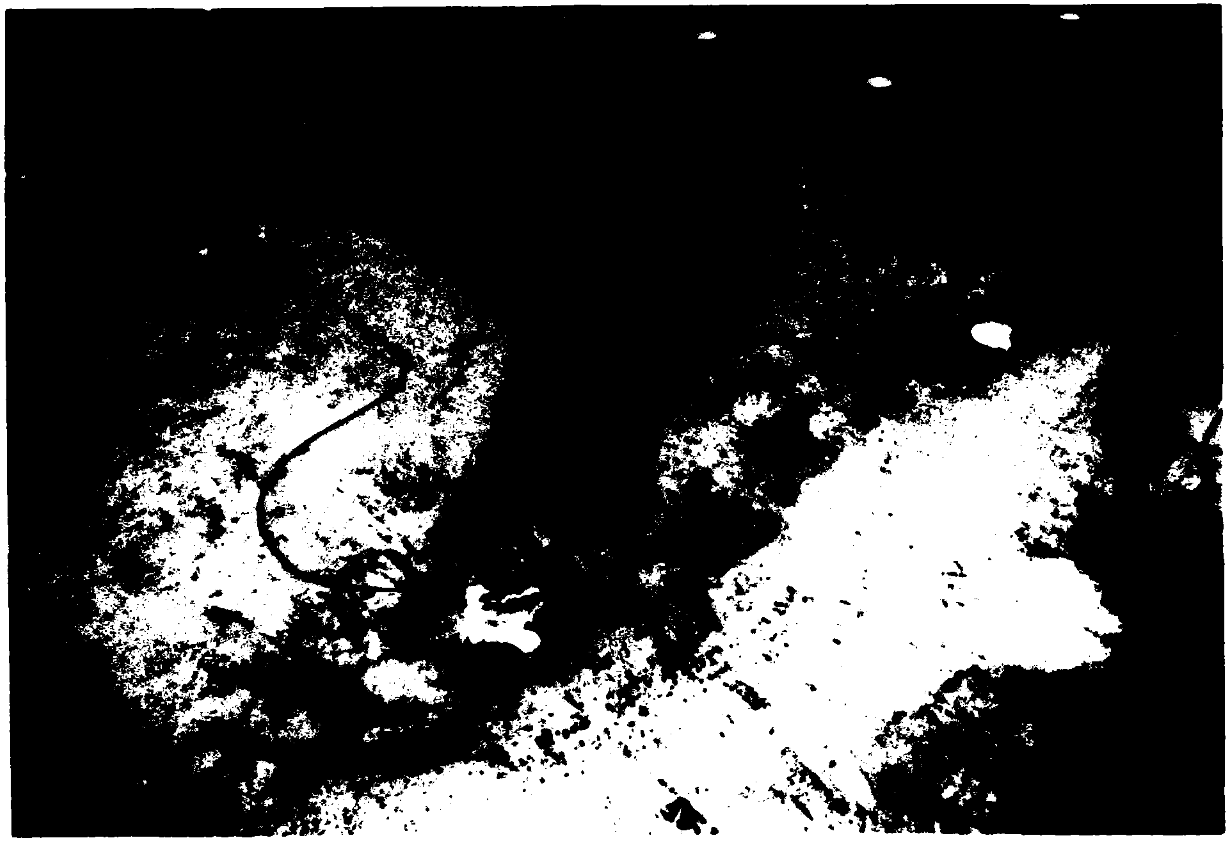
CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 7 sec
WAVE HEIGHT 4.5 ft
SEICHE HEIGHT 0

SHOALING TEST 4



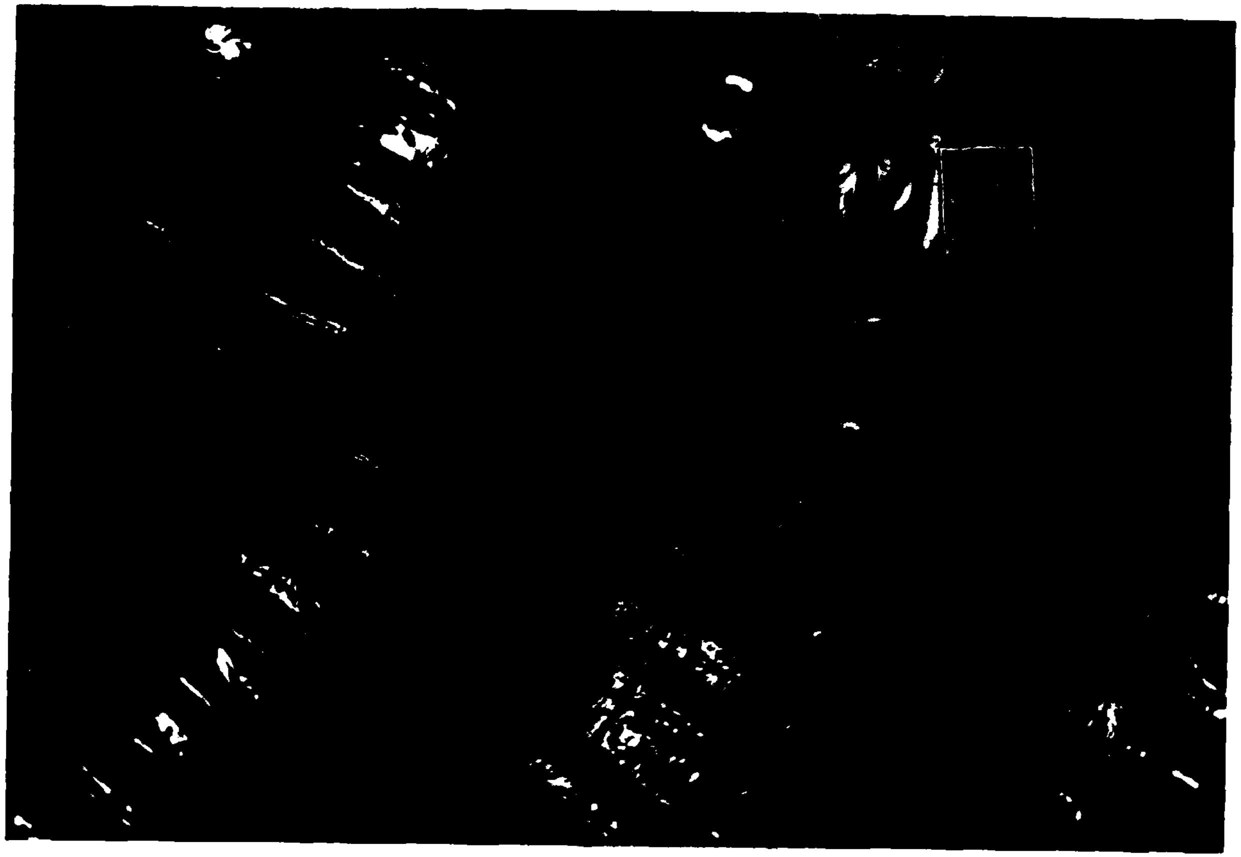
CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 5.0 ft
SEICHE HEIGHT 0

SHOALING TEST 5



CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 6



CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 7.0 ft
SEICHE HEIGHT 0.2 ft

SHOALING TEST 7

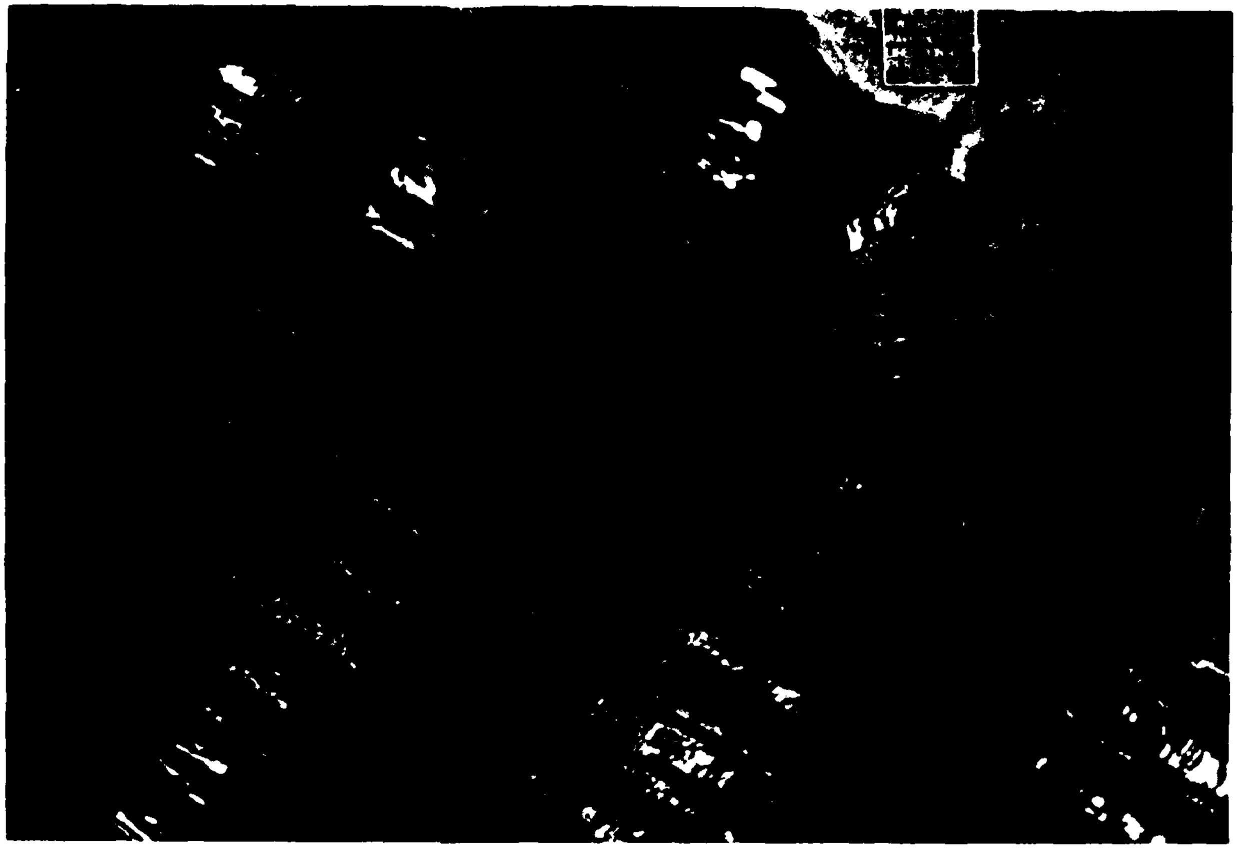
CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 8

PLATE 48

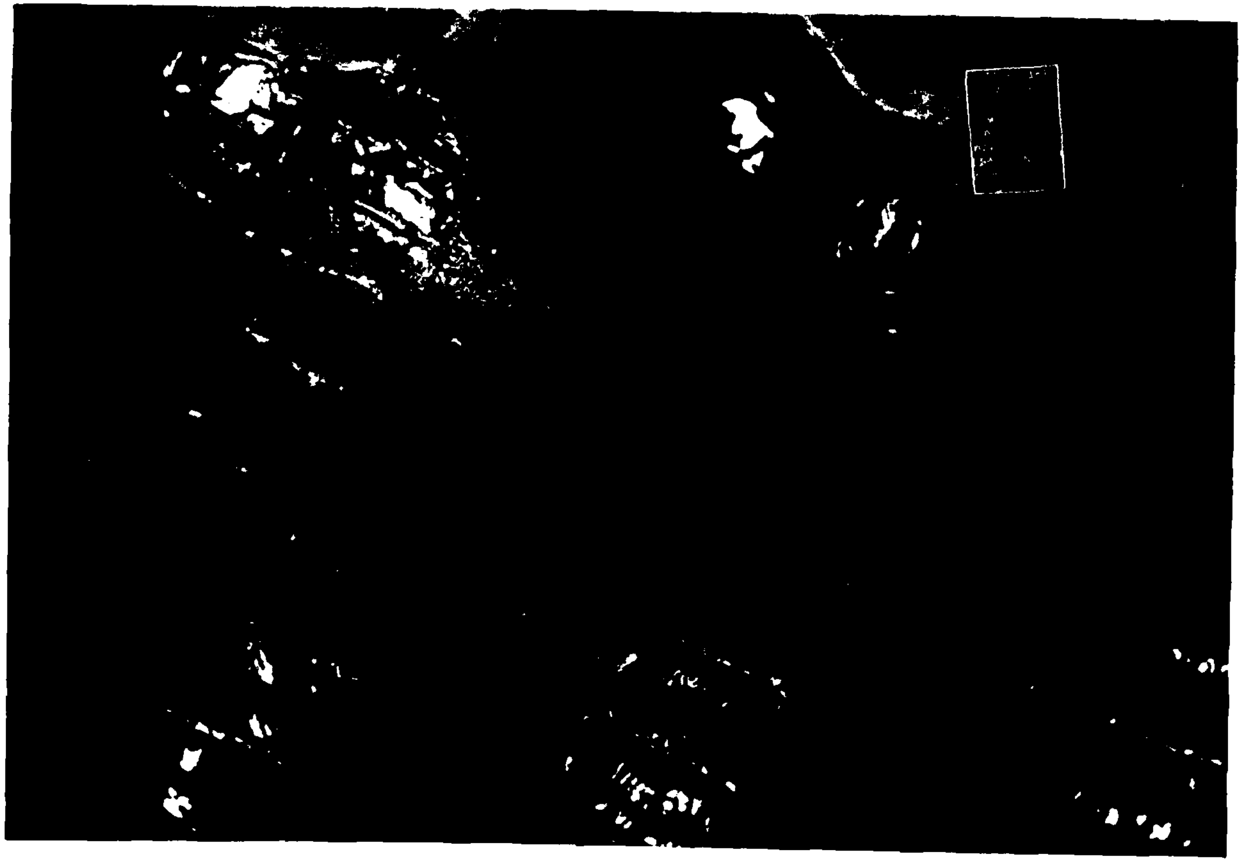
CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

DYE TEST 9



CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 10



CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 7 sec
WAVE HEIGHT 5 ft
SEICHE HEIGHT 0

SHOALING TEST 11

CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

SHOALING TEST 12

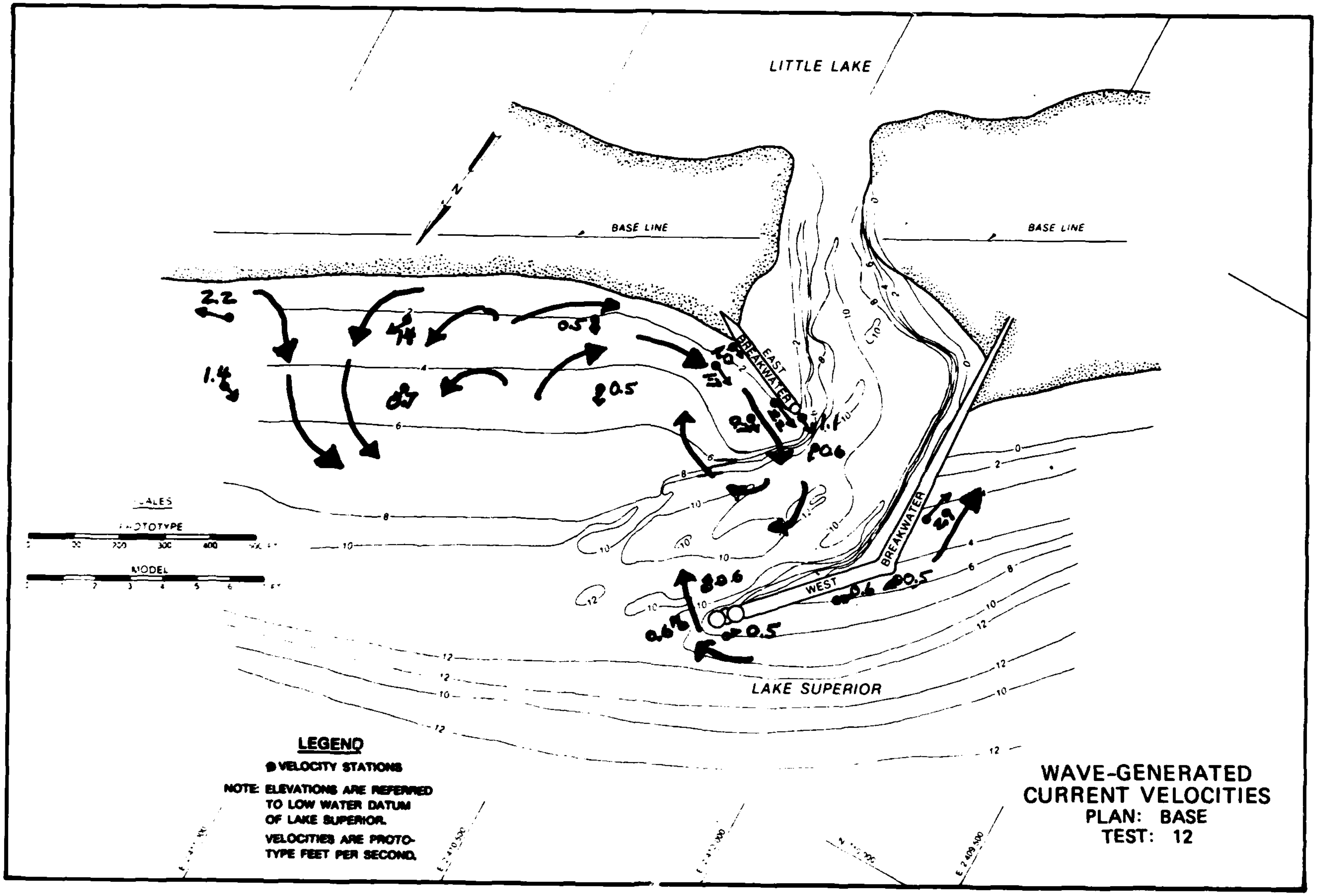
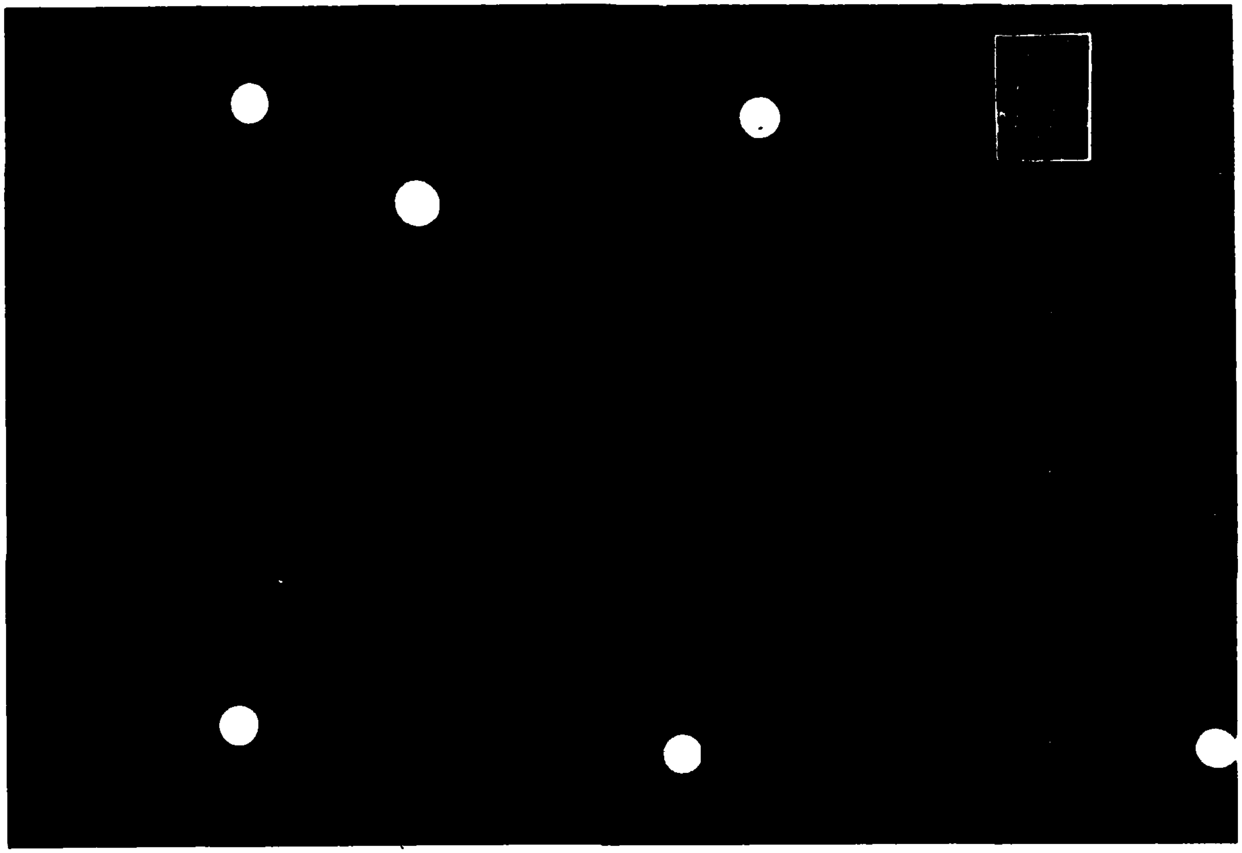

LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
N
2.2
1.4
0.5
0.5
0.6
1.1
0.6
0.6
0.6
0.5
0.5
SCALES
PROTOTYPE
MODEL
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 12

PLATE 53



CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 13

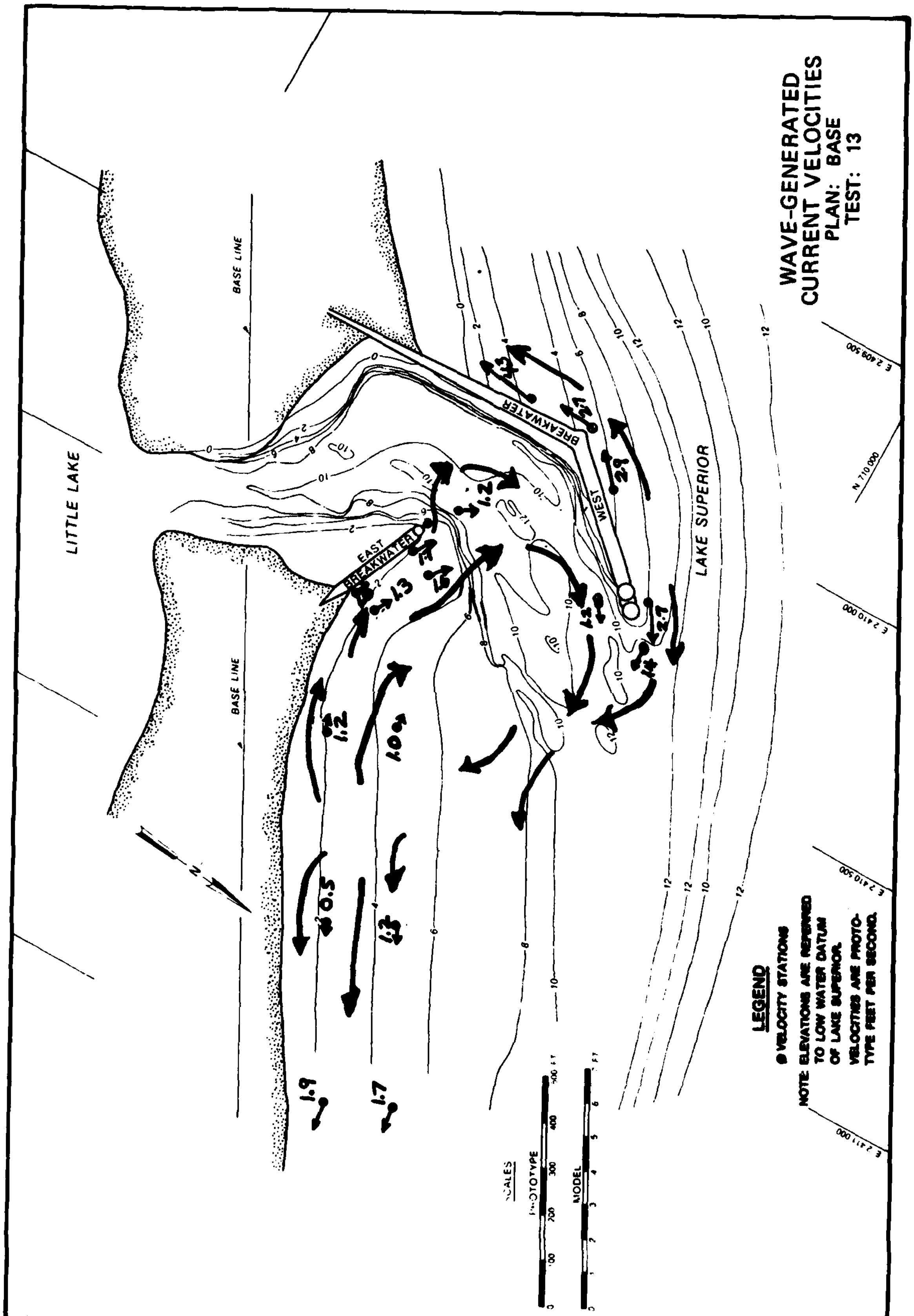

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 13
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 55

CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 7 sec
WAVE HEIGHT 6 ft
SEICHE HEIGHT 0

SHOALING TEST 14

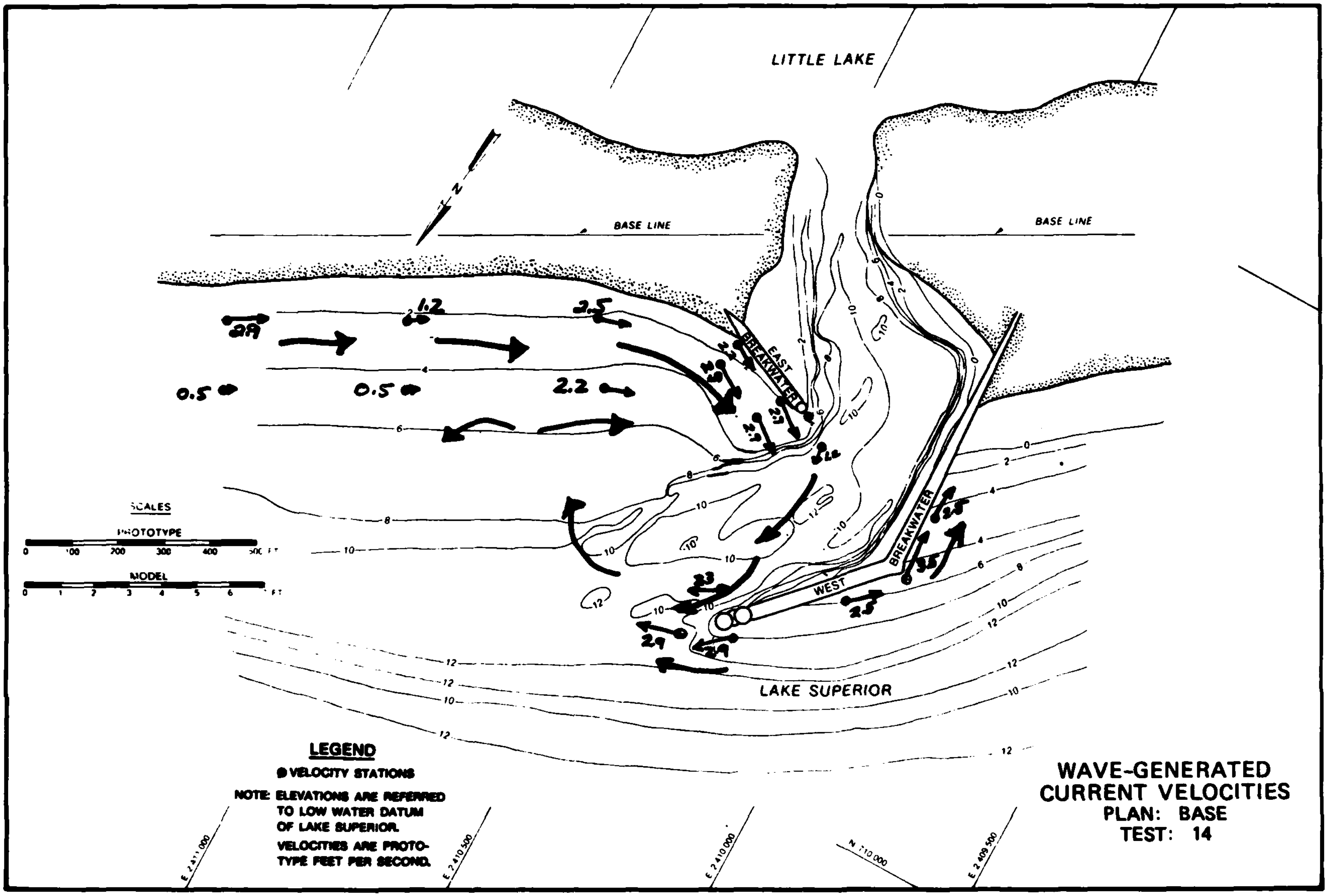
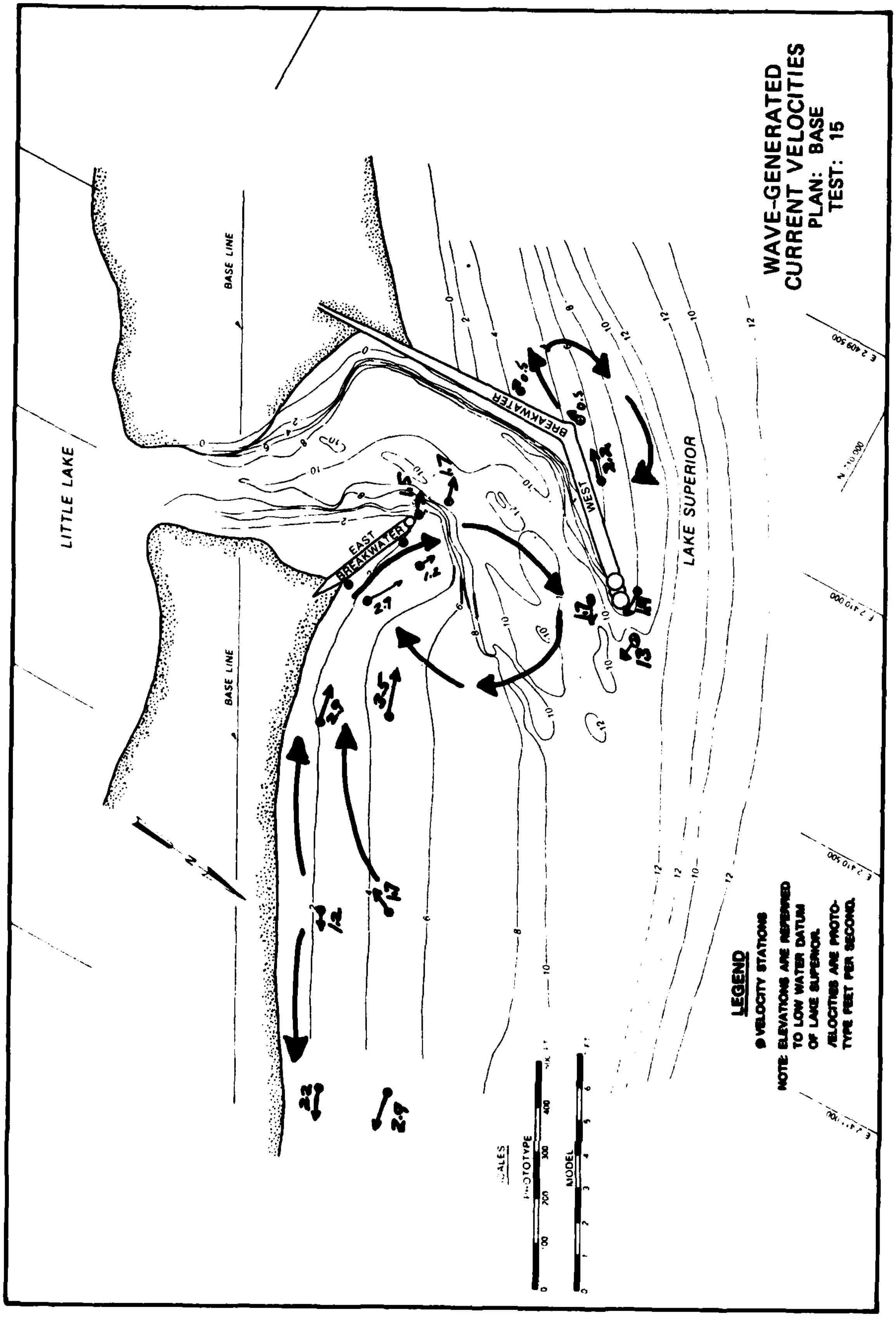

LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
MODEL
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 14

PLATE 57

CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 7 sec
WAVE HEIGHT 12 ft
SEICHE HEIGHT 0

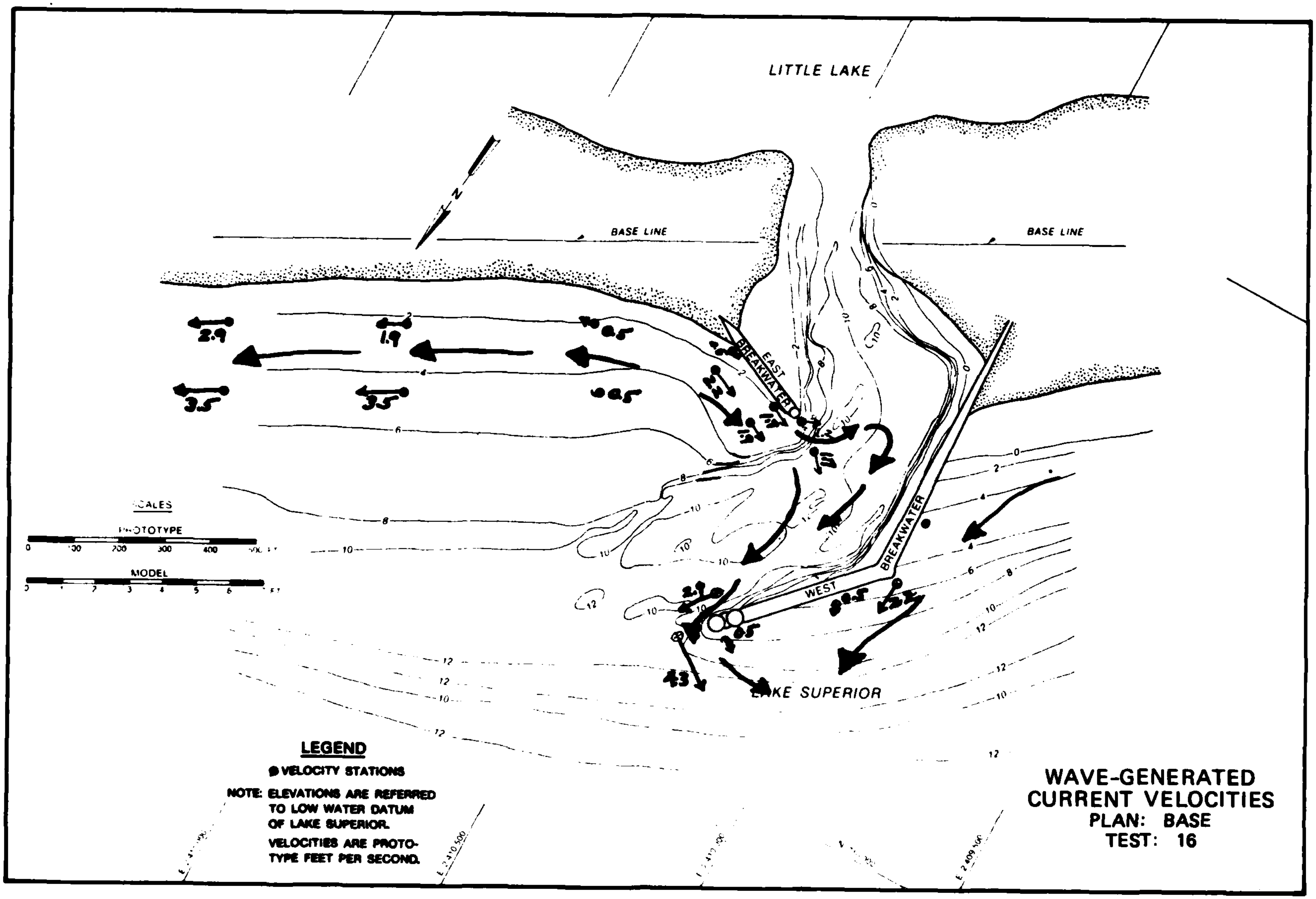
SHOALING TEST 15



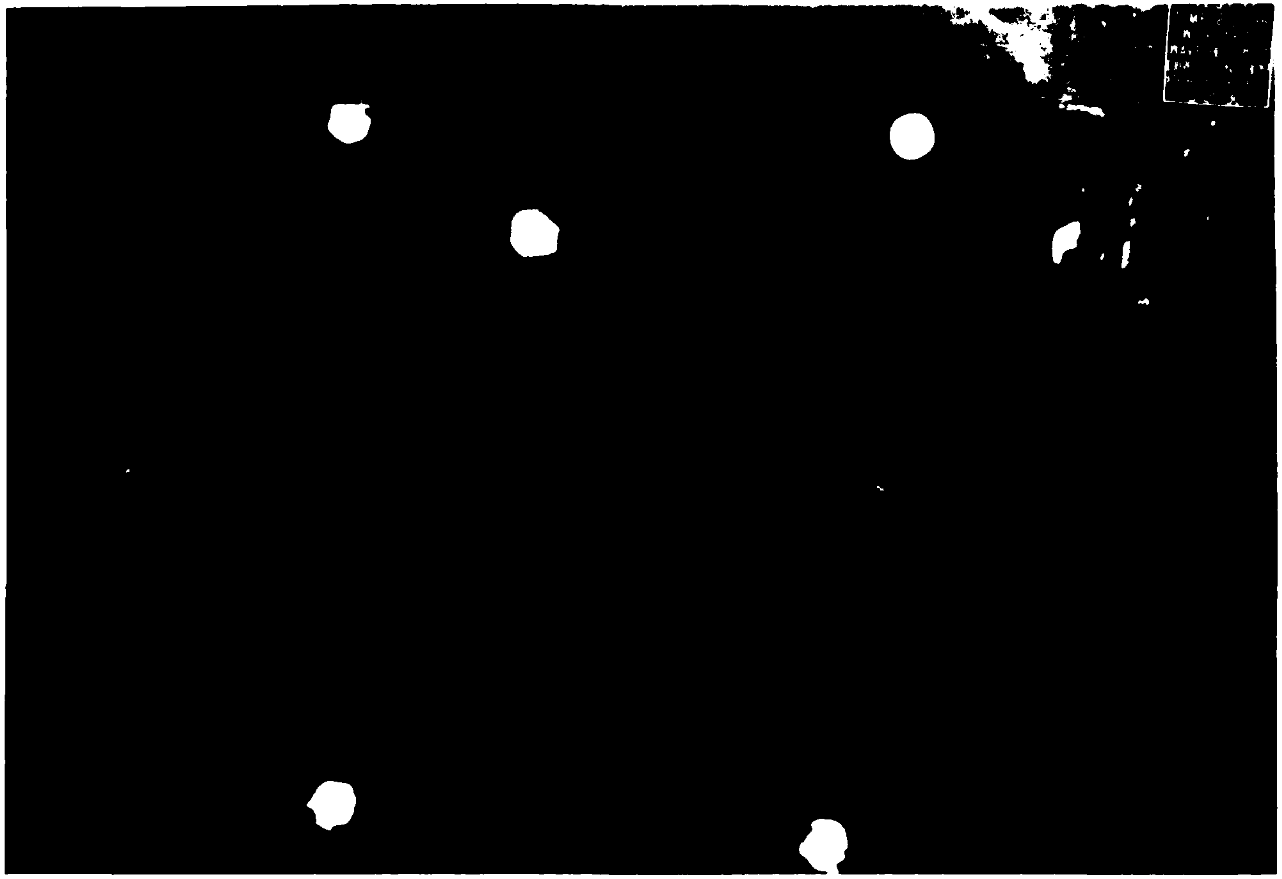
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 15
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 9 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 16

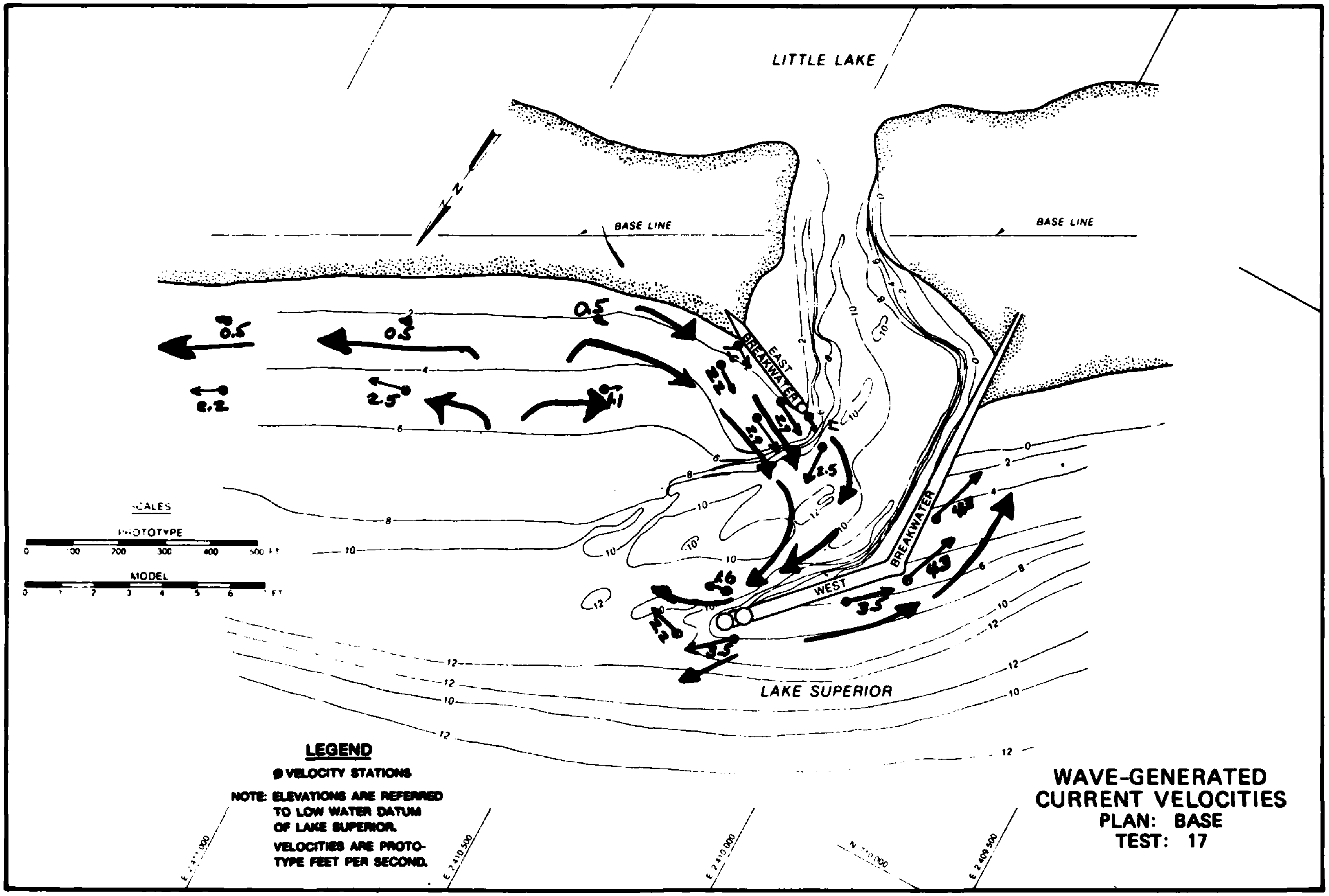


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 16



CONDITION Base
WAVE DIRECTION 330°
WAVE PERIOD 9 sec
WAVE HEIGHT 21 ft
SEICHE HEIGHT 0

SHOALING TEST 17



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 17
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
E 2 410 500
E 2 410 000
E 2 409 500

PLATE 63

CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

SHOALING TEST 18

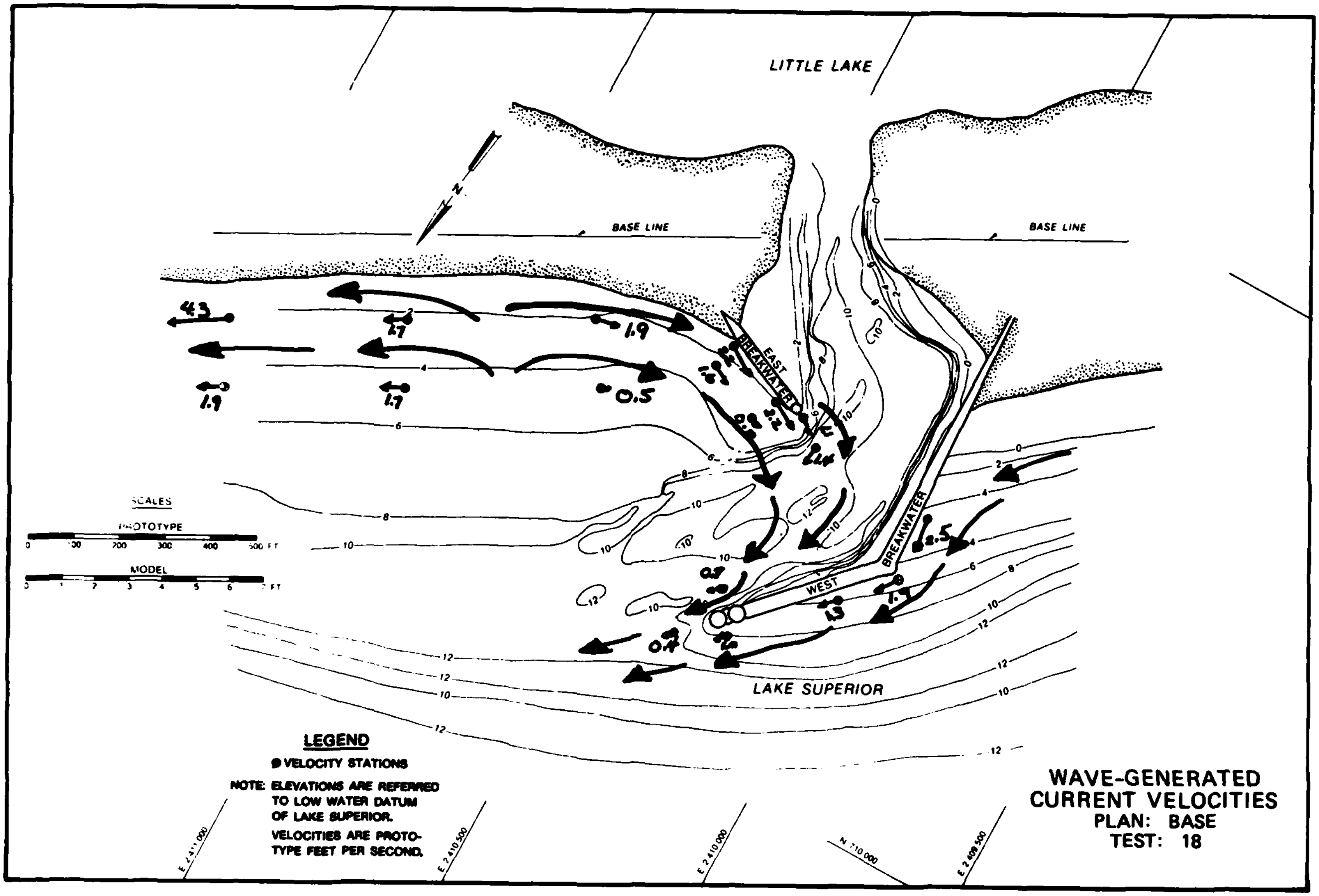
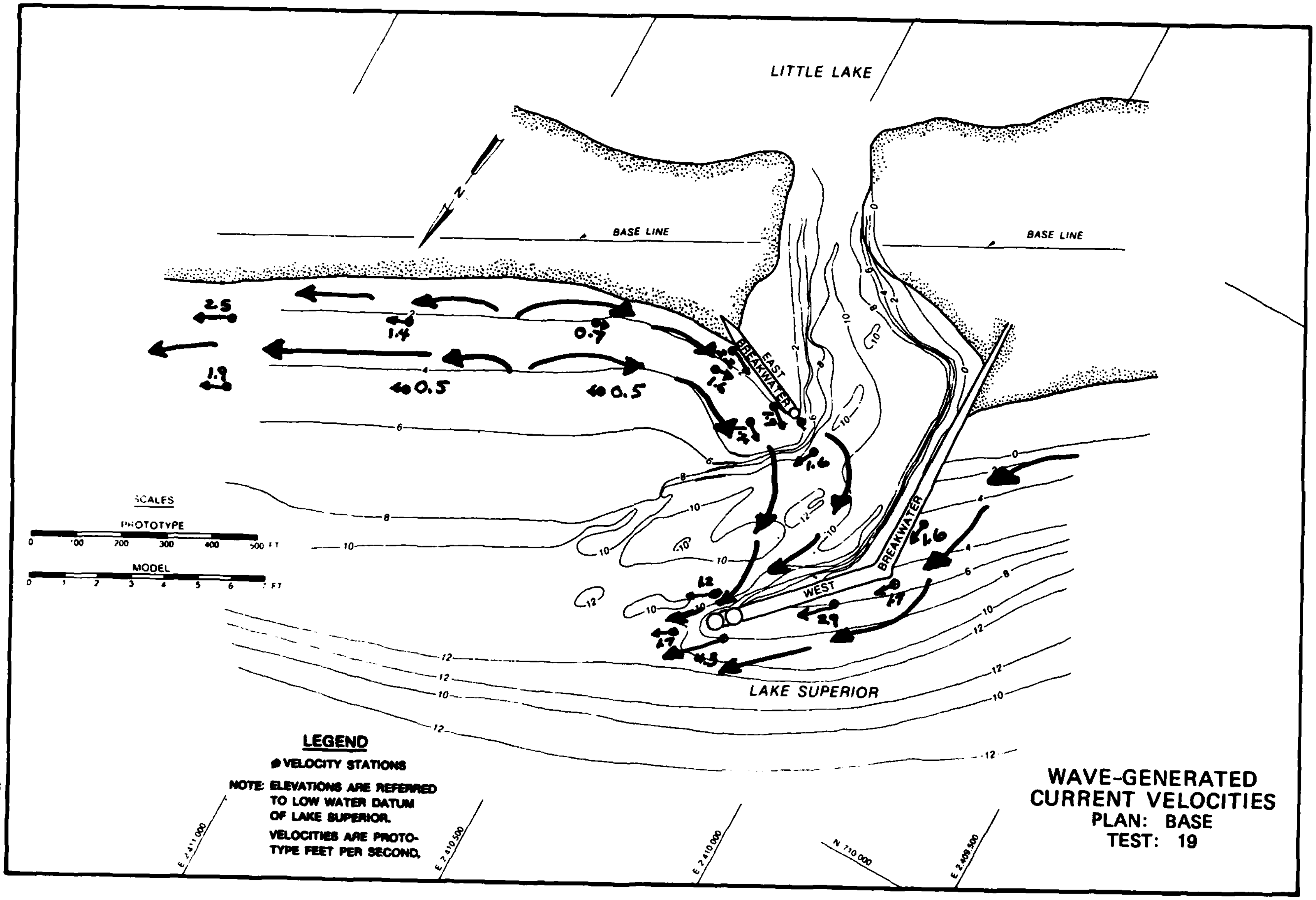

LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 18
4.3
1.9
1.7
0.5

PLATE 65

CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 19

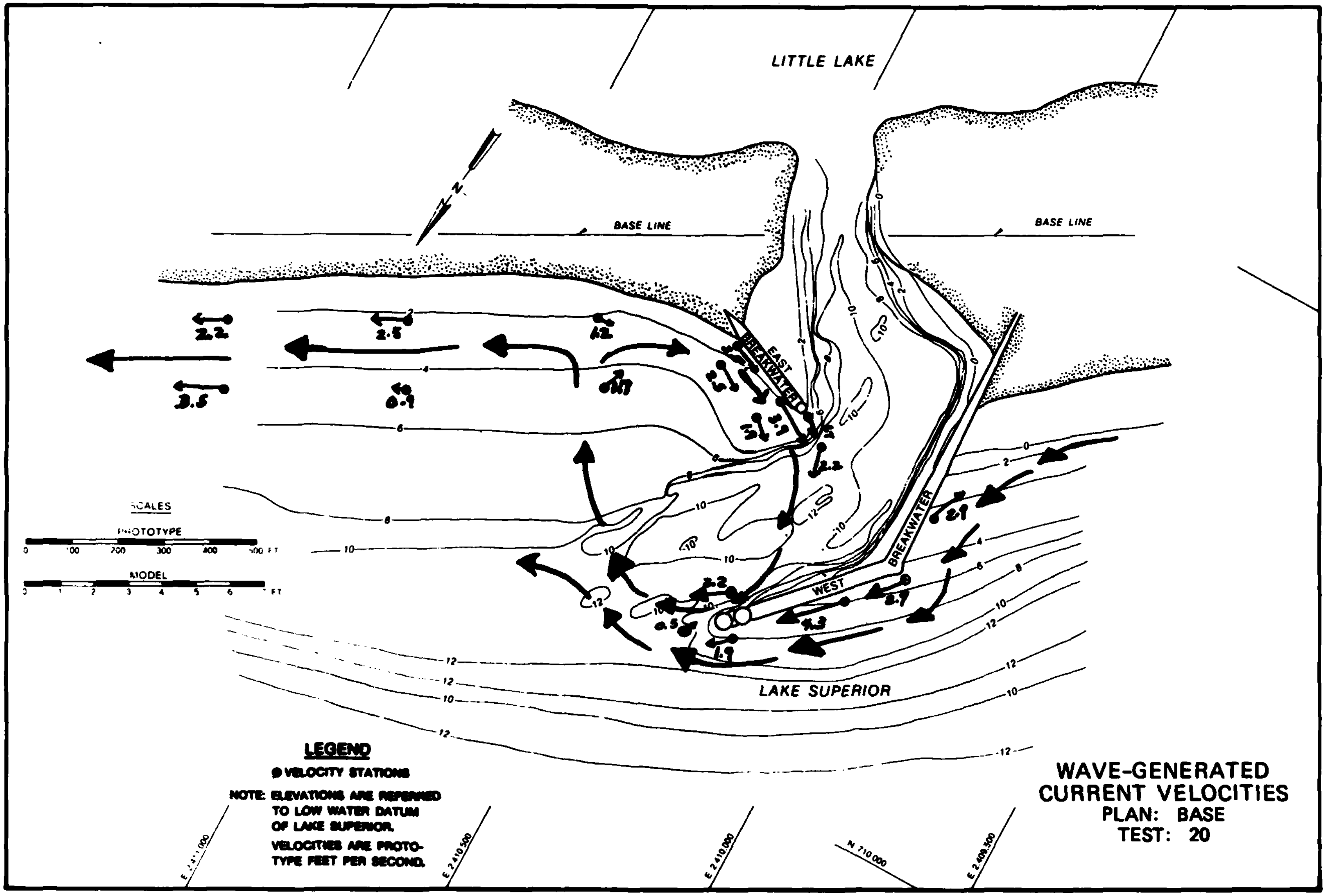


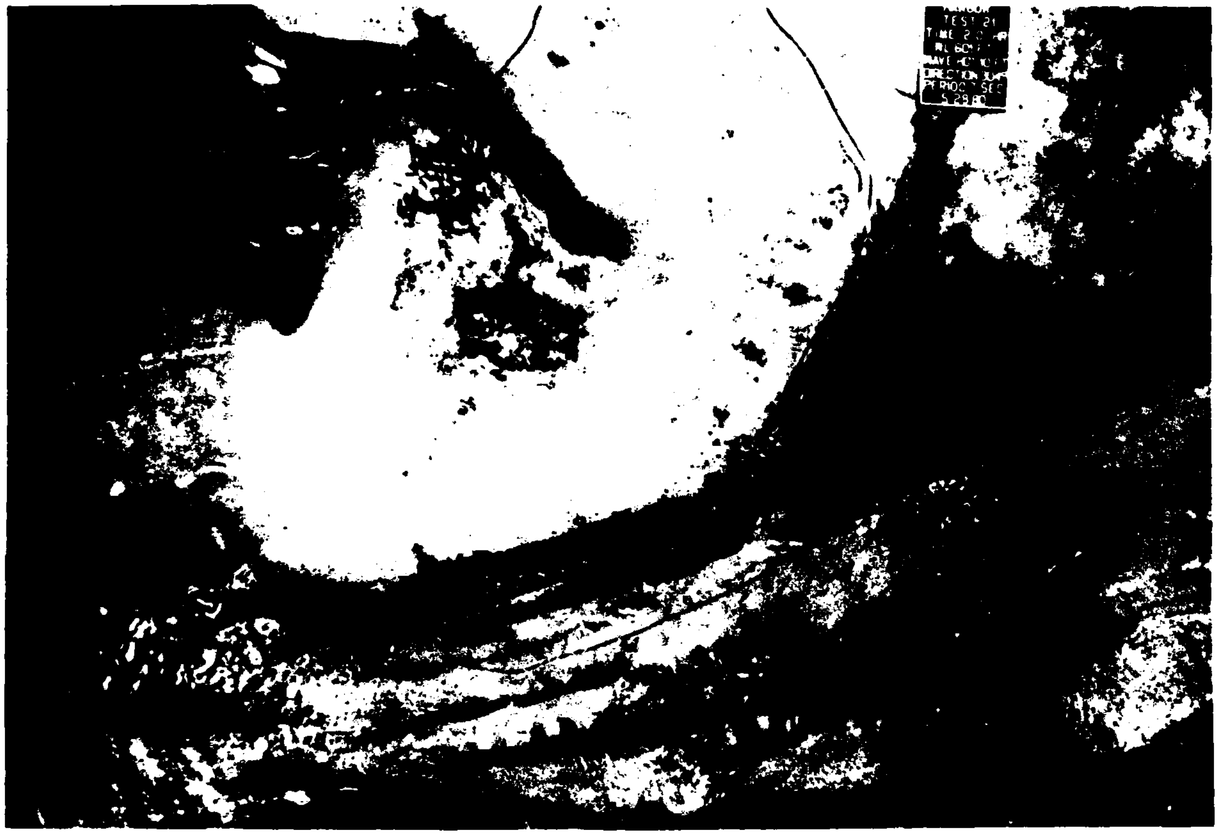
LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 411 000
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 19

PLATE 67

CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 5 ft
SEICHE HEIGHT 0

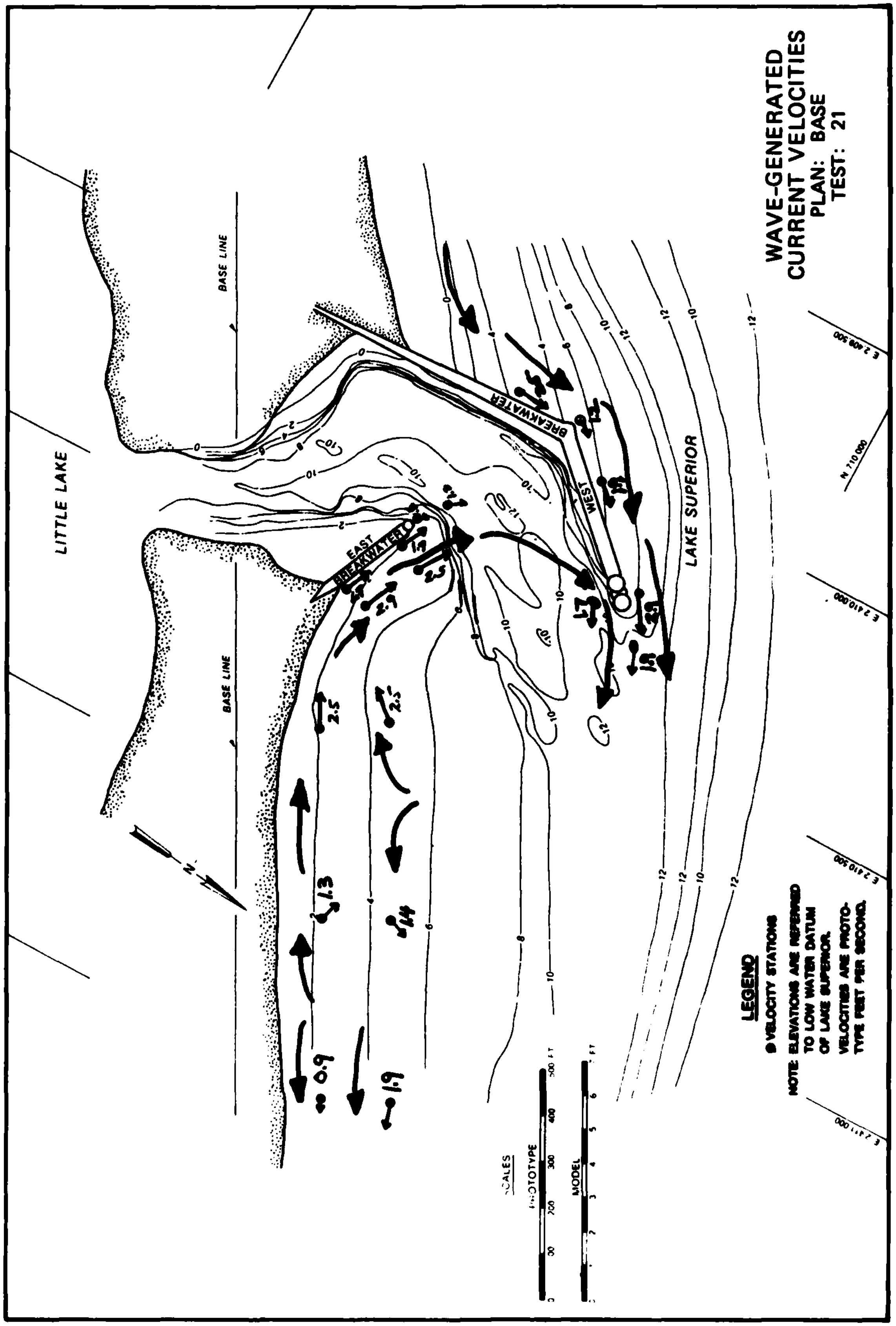
SHOALING TEST 20


LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
⊕ VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 20

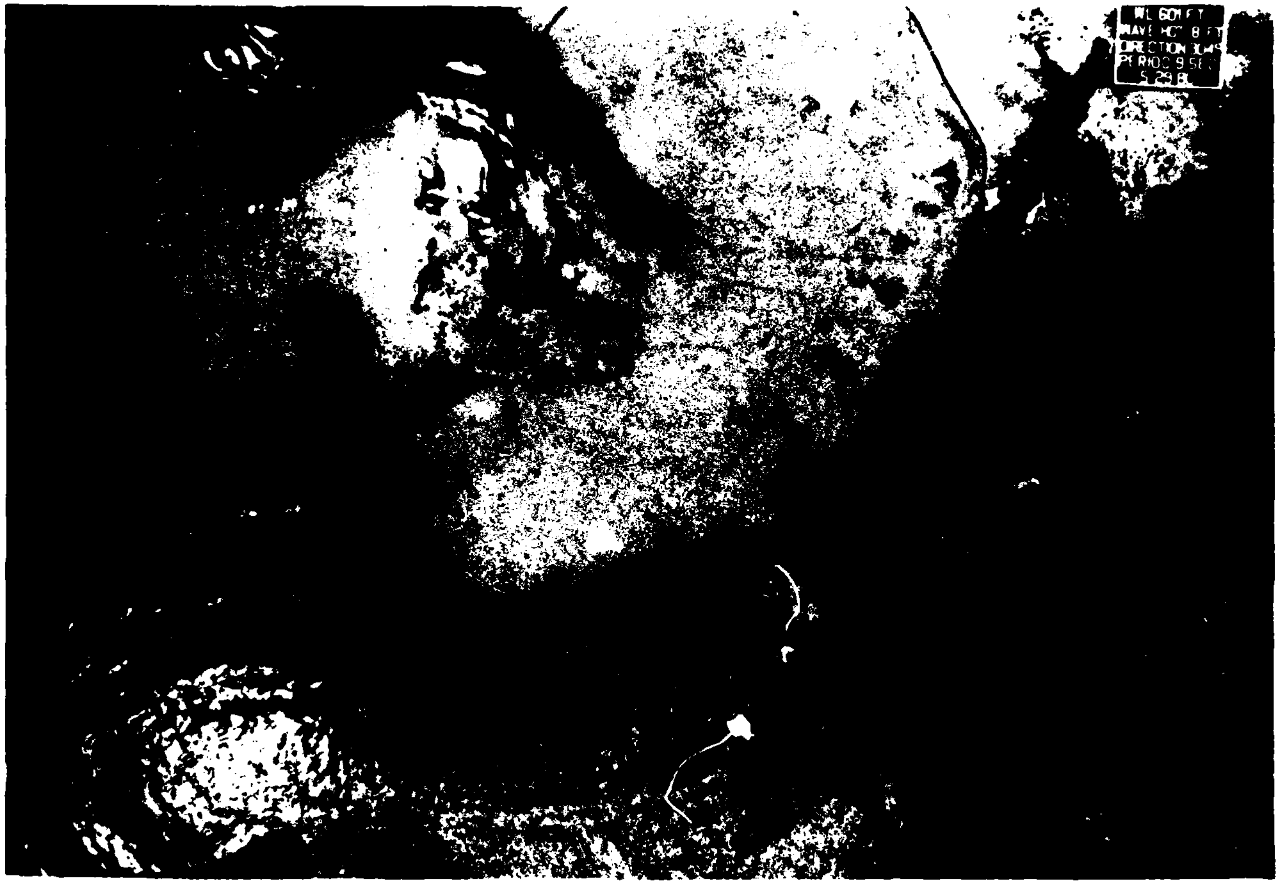


CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 21

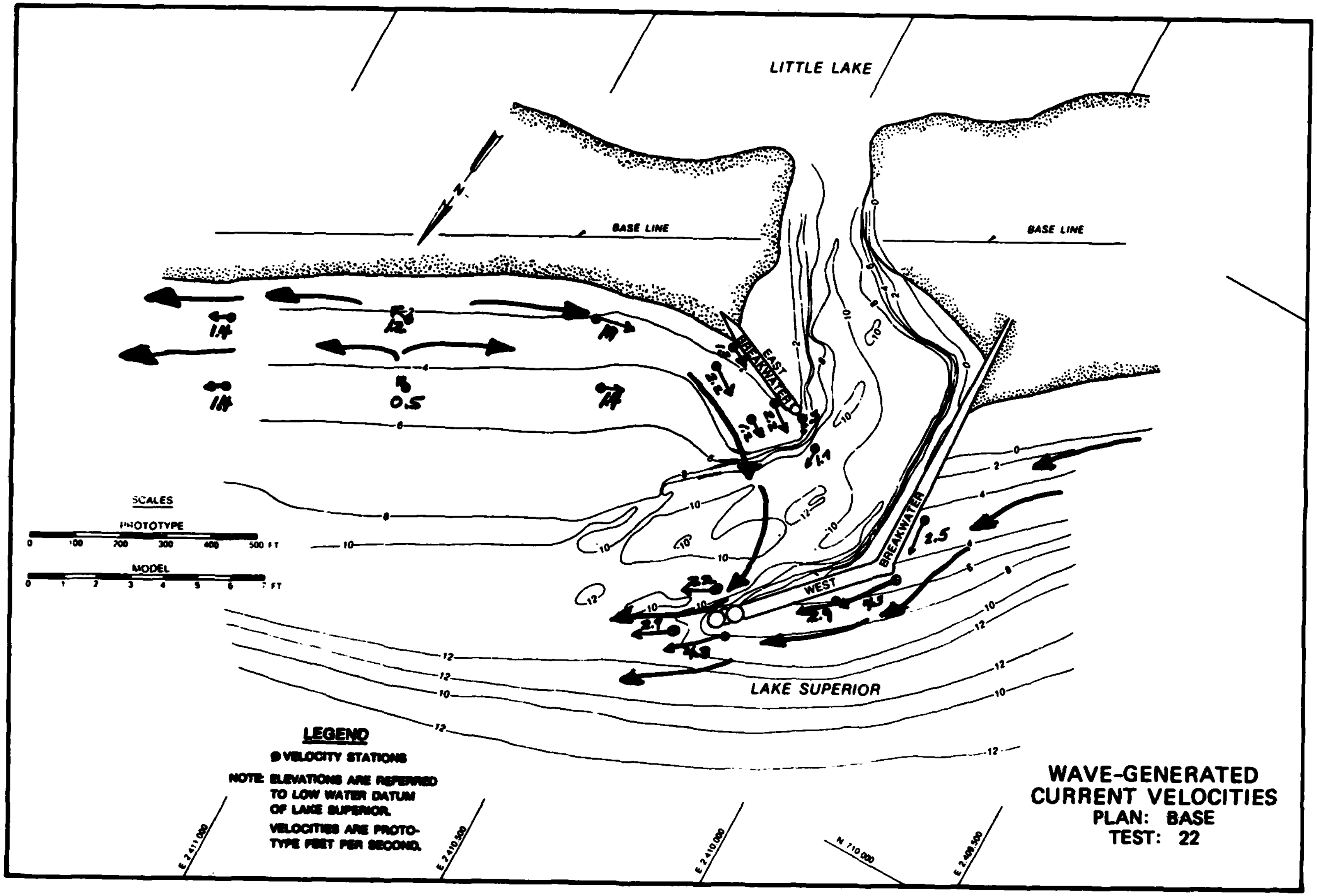


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 21
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
WEST BREAKWATER
EAST BREAKWATER
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL



CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 22



LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 22

PLATE 73

CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 17 ft
SEICHE HEIGHT 0

SHOALING TEST 23

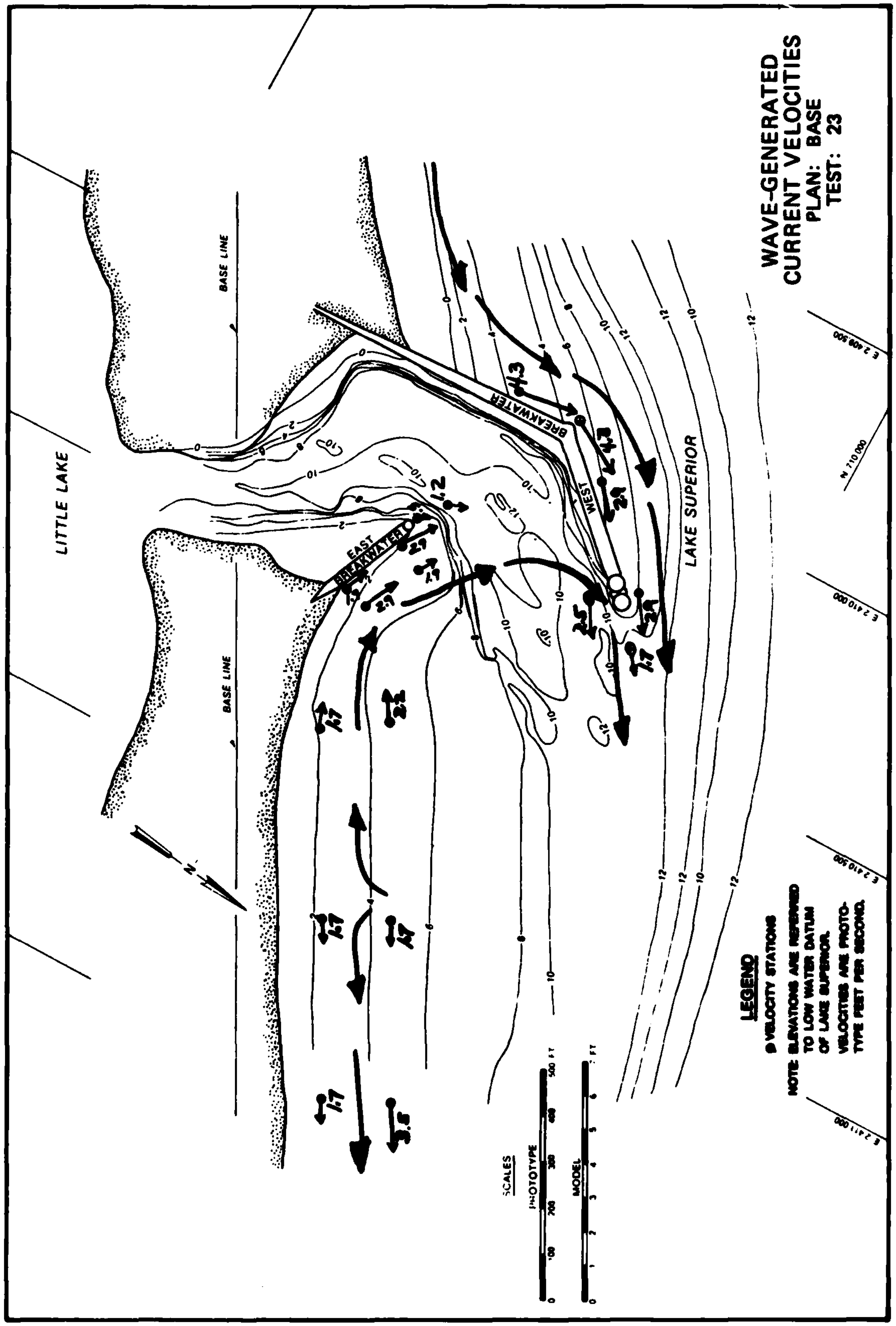
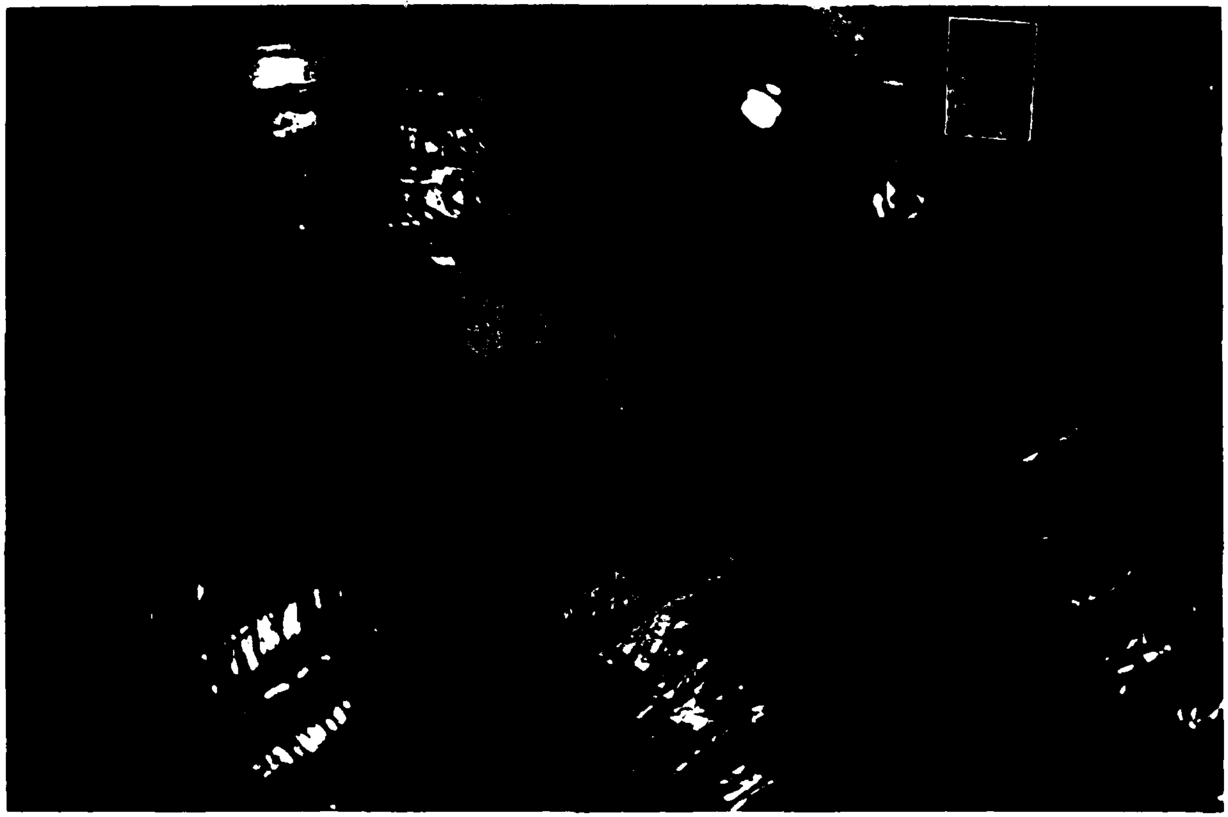

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 23
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 75



CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

SHOALING TEST 24

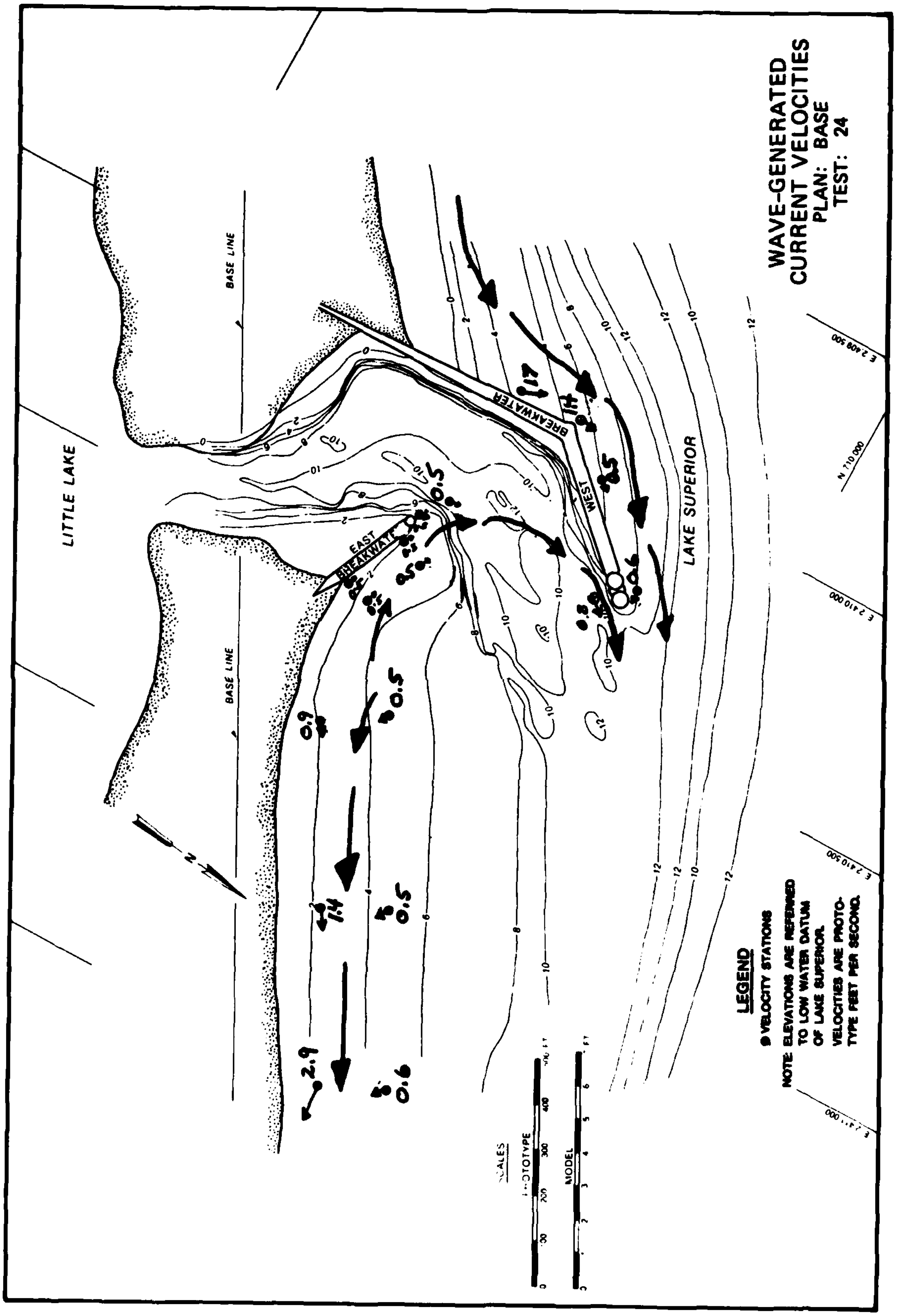
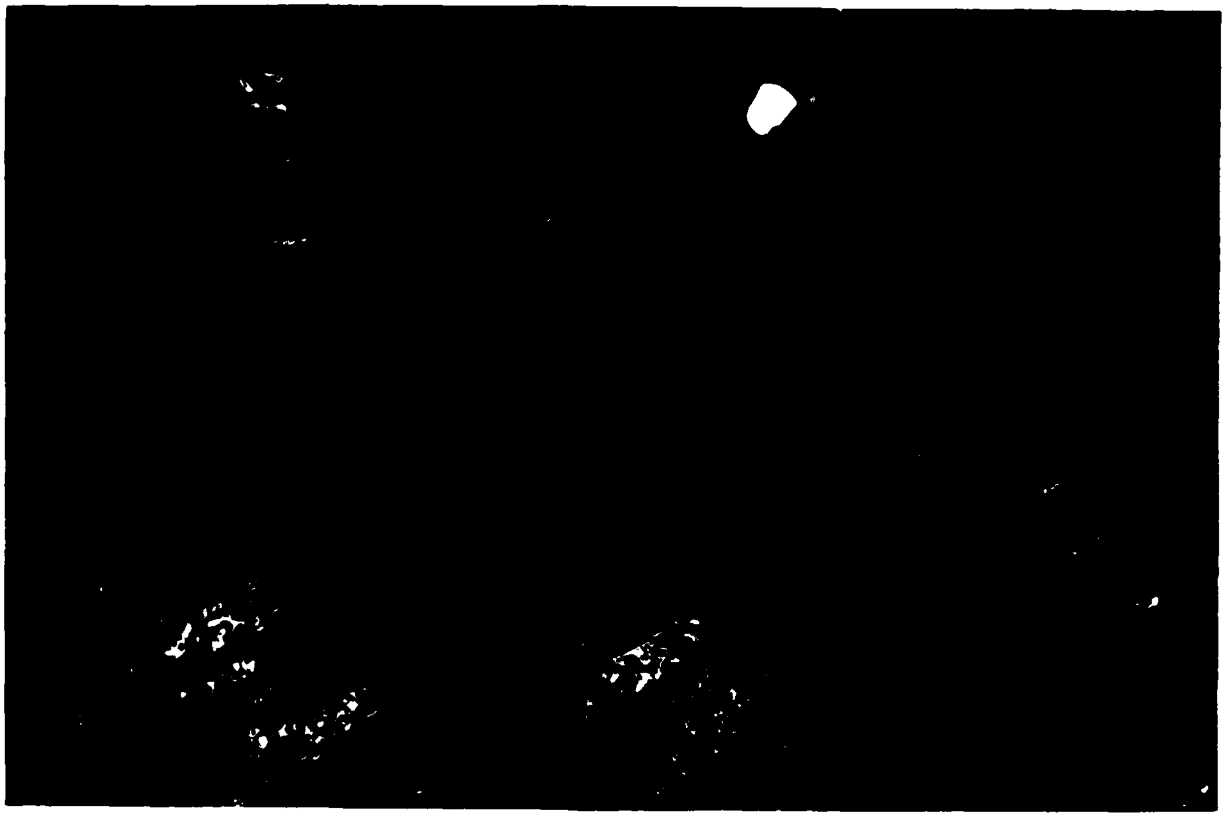

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 24
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

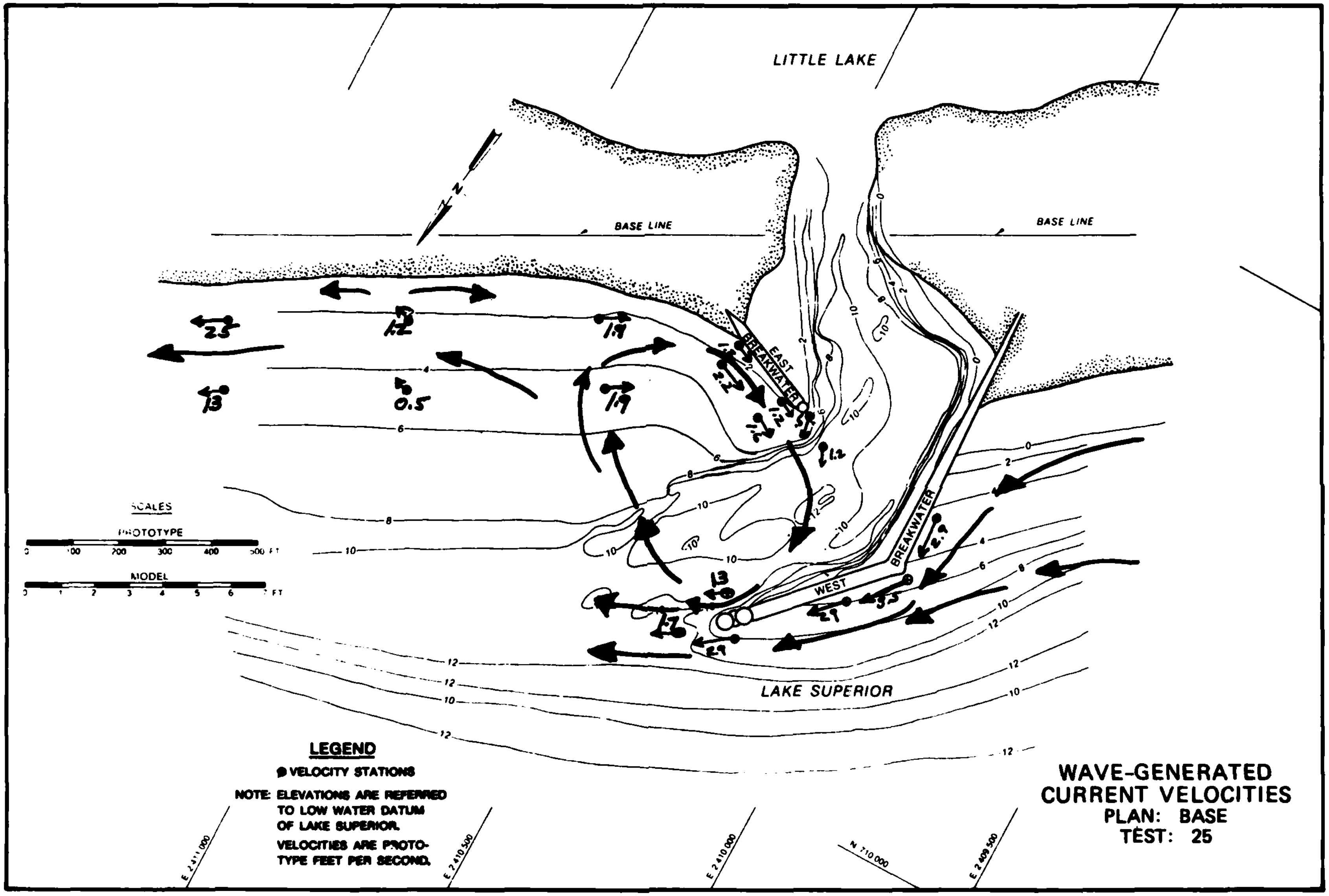
PLATE 77

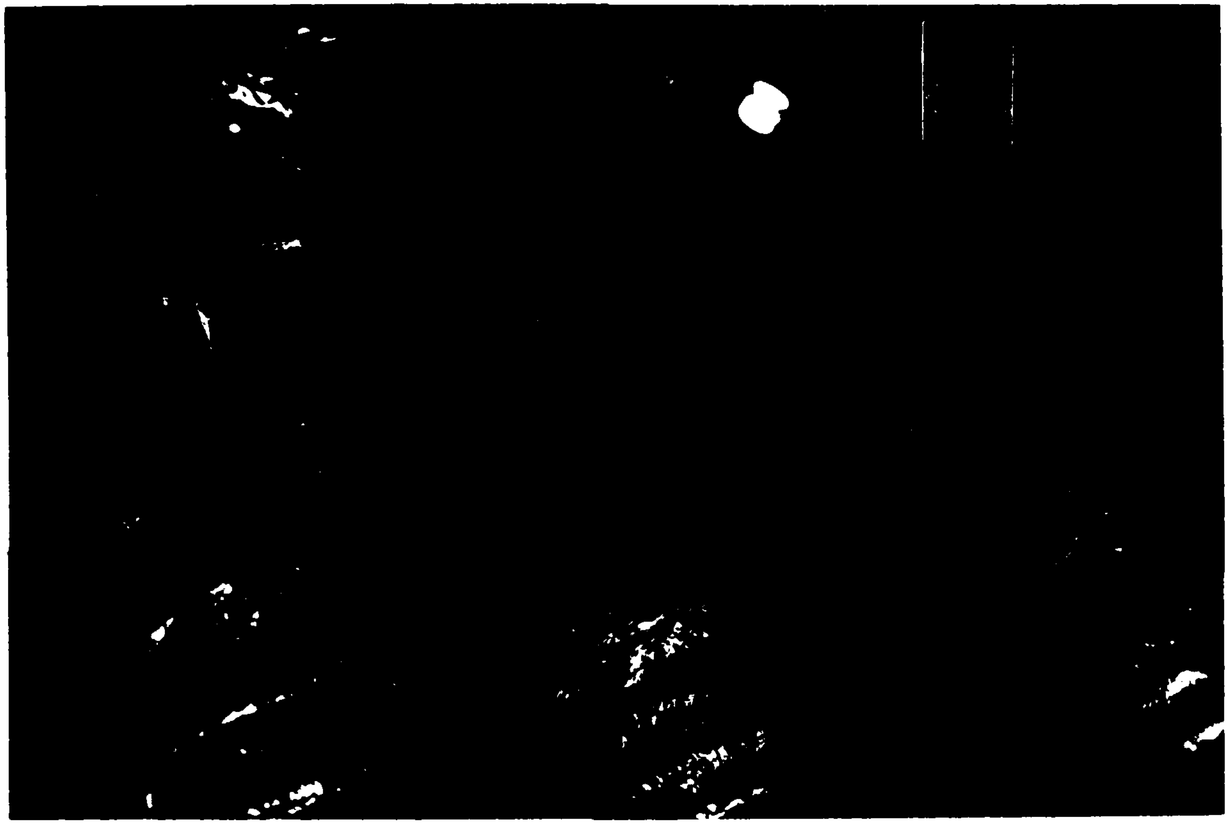


CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 25

PLATE 78

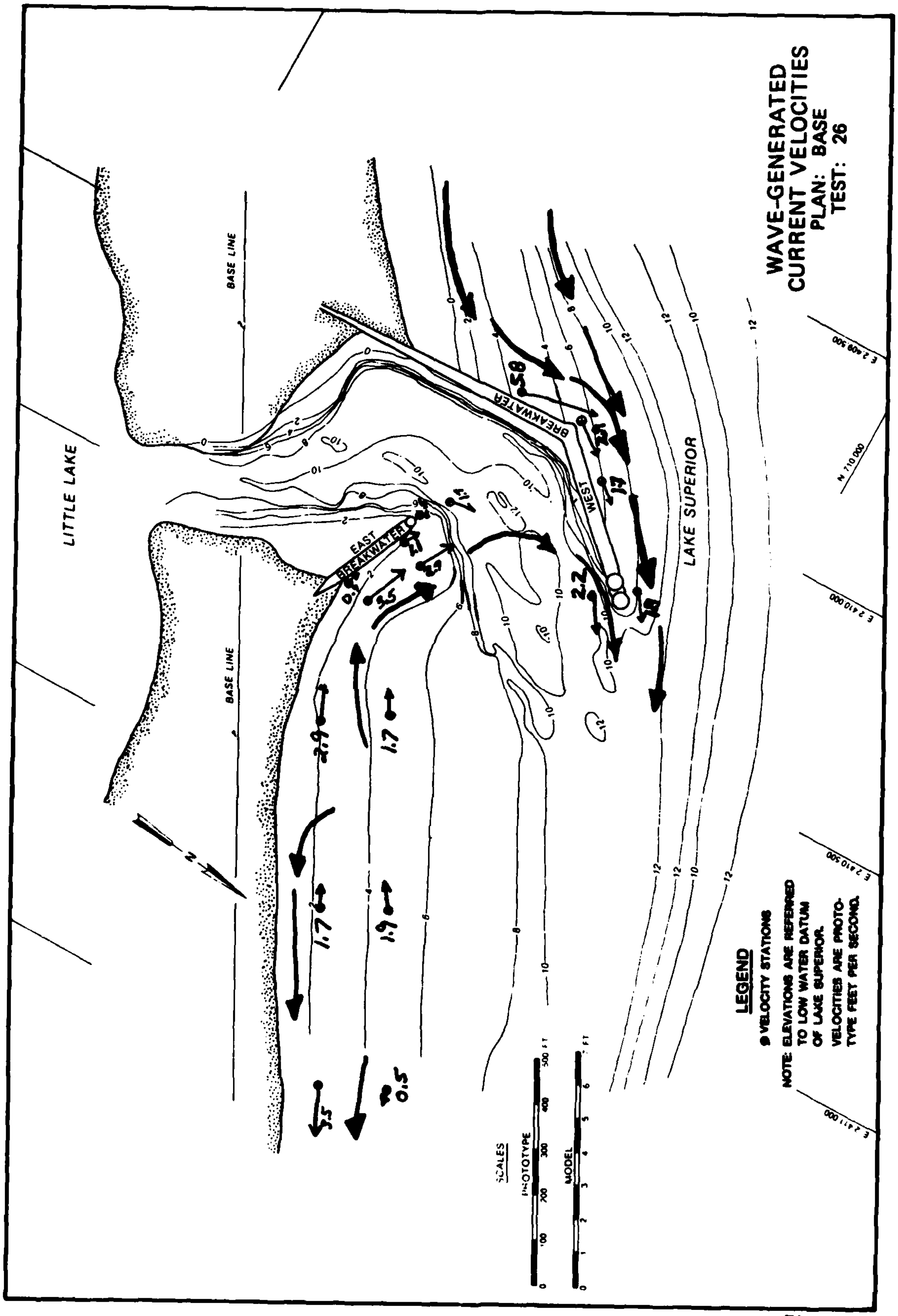

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 25
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
E 2 409 500
E 2 410 000
E 2 410 500
N 710 000



CONDITION base
WAVE DIRECTION 278°
WAVE PERIOD 7 sec
WAVE HEIGHT 5 ft
SEICHE HEIGHT 0

SHOALING TEST 26

PLATE 80



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 26
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
N 710 000
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
5.8
2.1
1.7
2.2
1.8
1.1
2.7
2.9
3.5
0.5
2.9
1.7
1.7
1.9
0.5
3.5

PLATE 81

CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 27

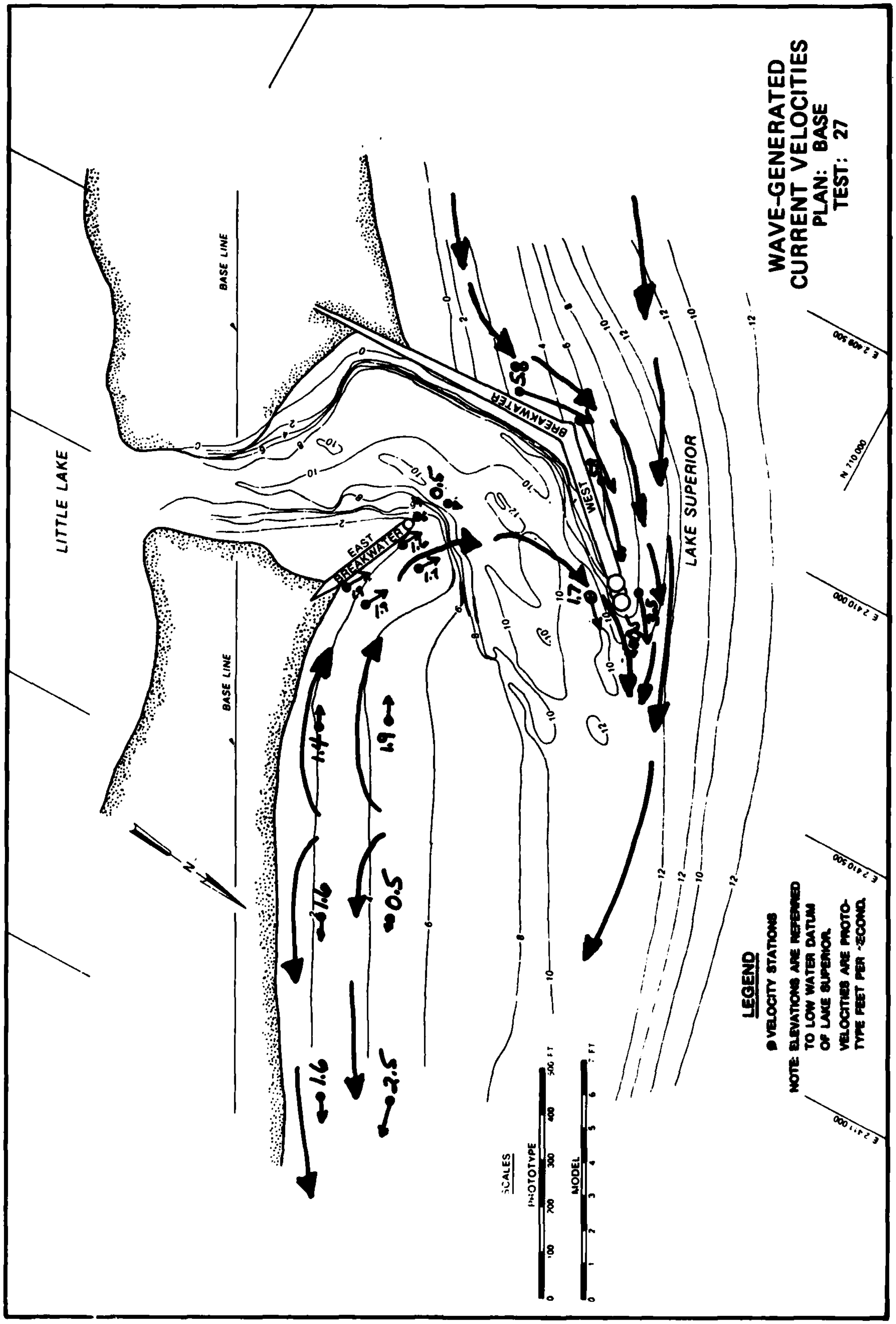

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 27
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 83

CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 28

PLATE 84

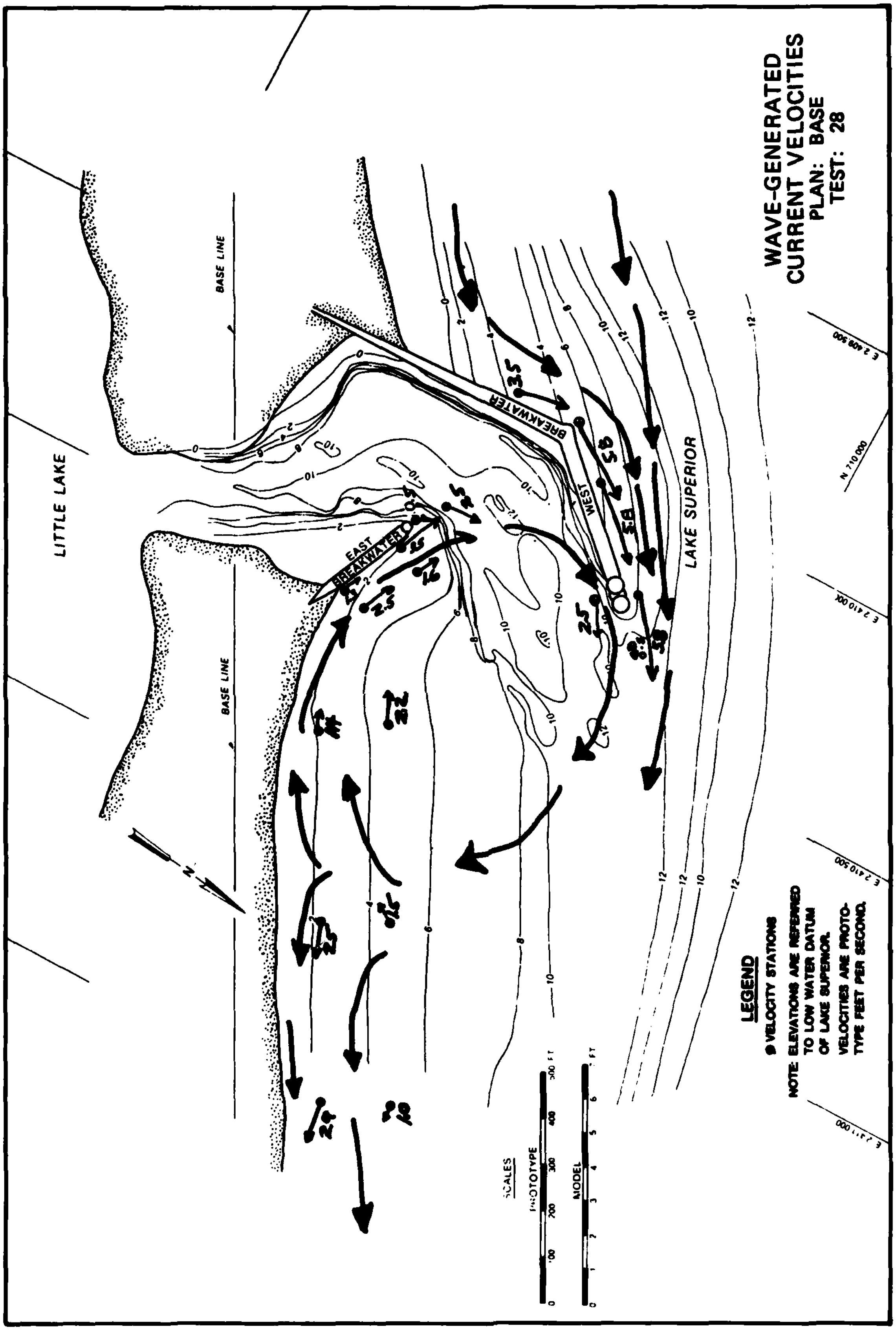

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 28
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 85

CONDITION Base
WAVE DIRECTION 278°
WAVE PERIOD 9 sec
WAVE HEIGHT 17 ft
SEICHE HEIGHT 0

SHOALING TEST 29

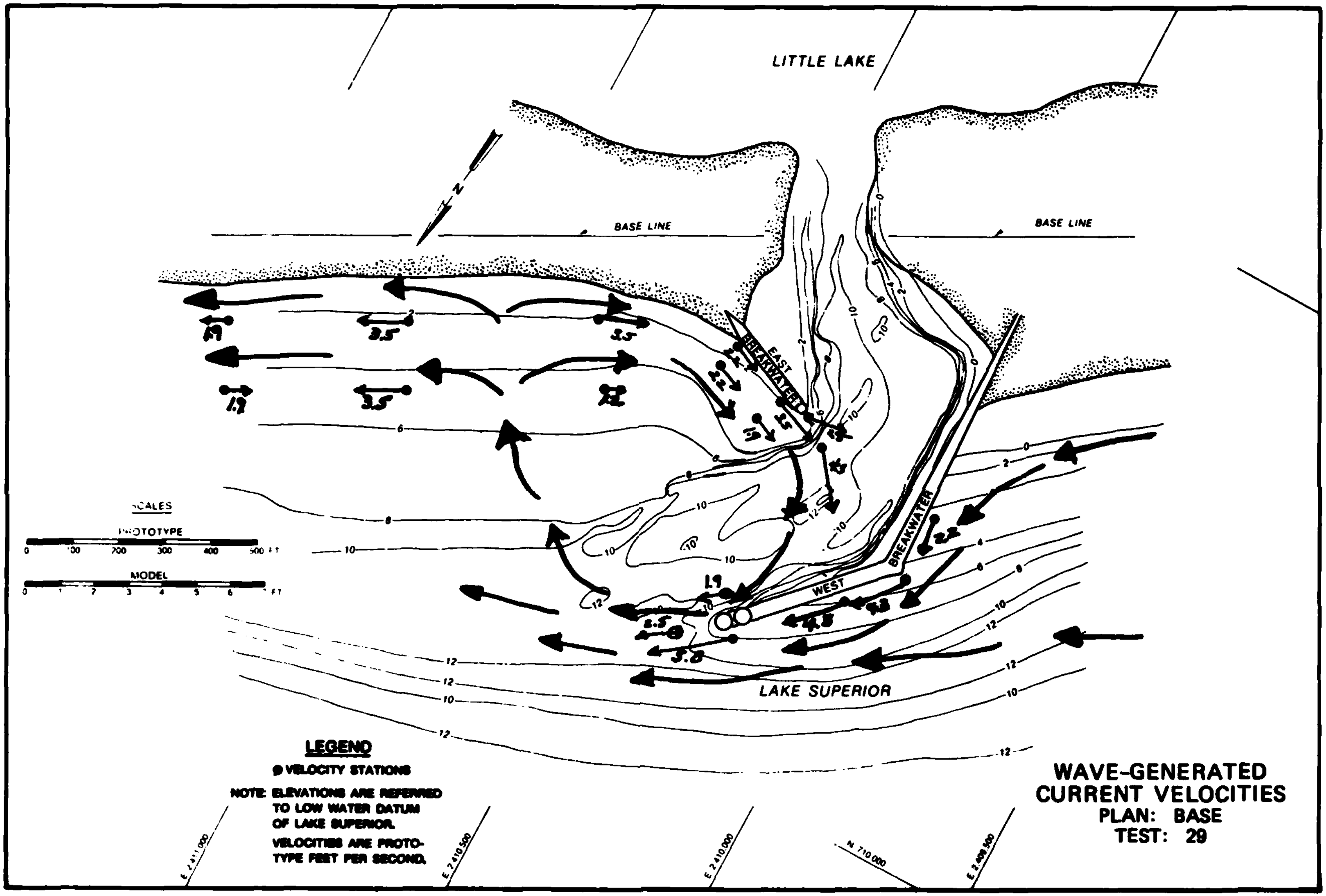
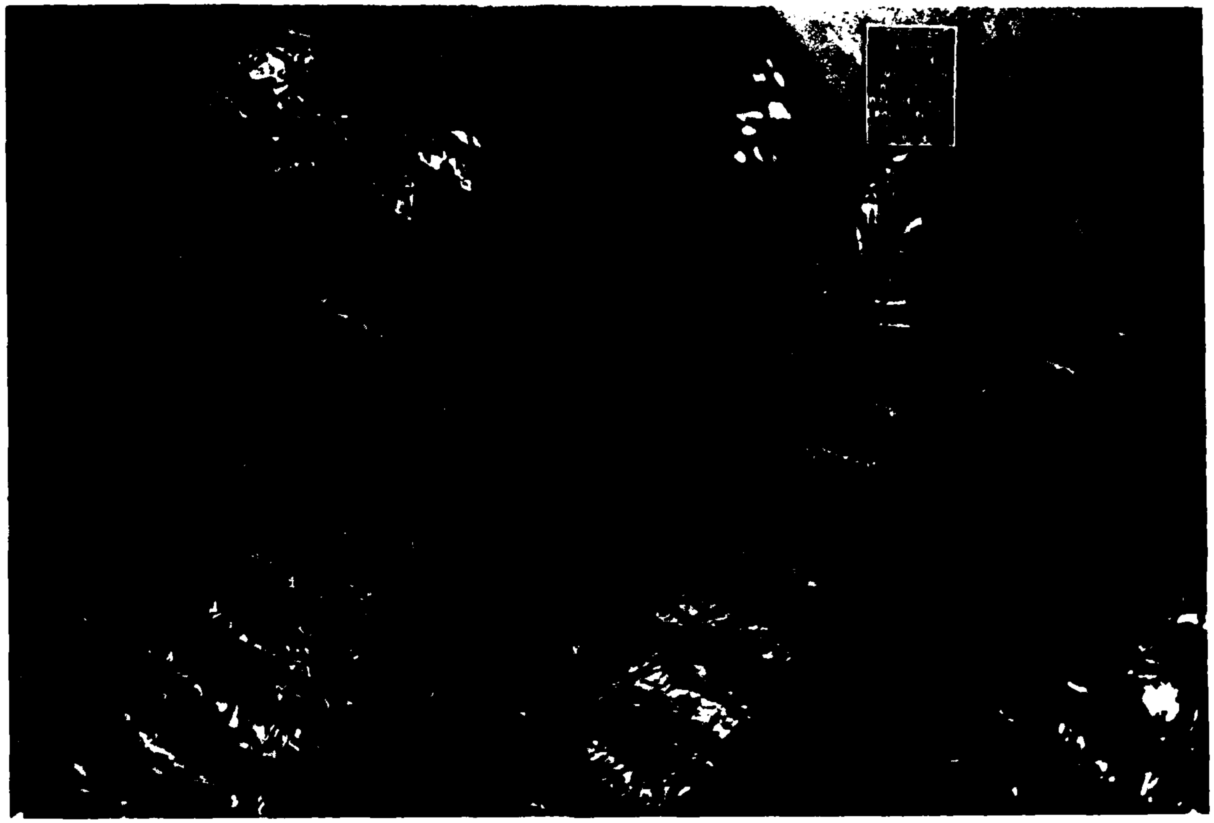

LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
MODEL
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 29

PLATE 87



CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

SHOALING TEST 30

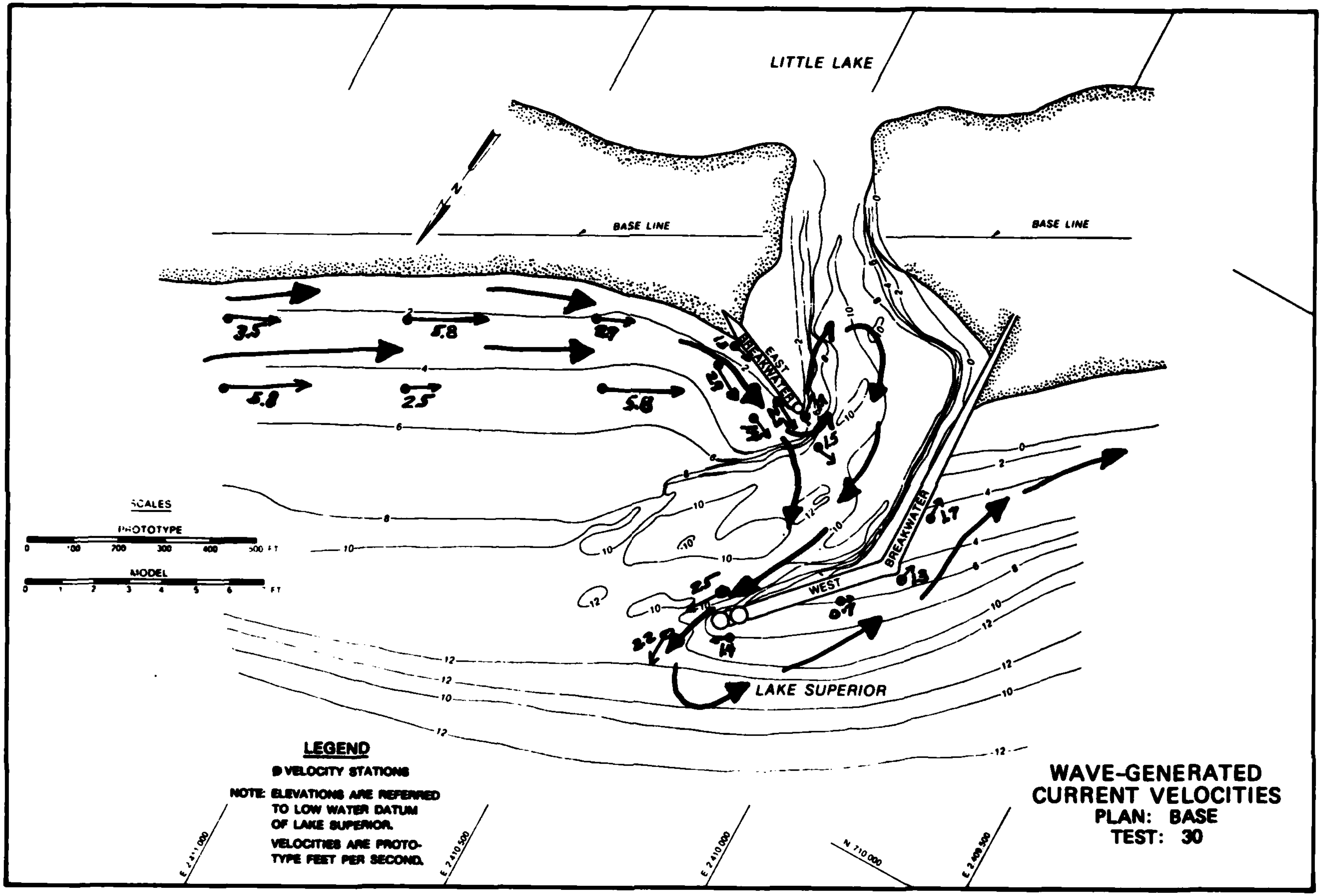
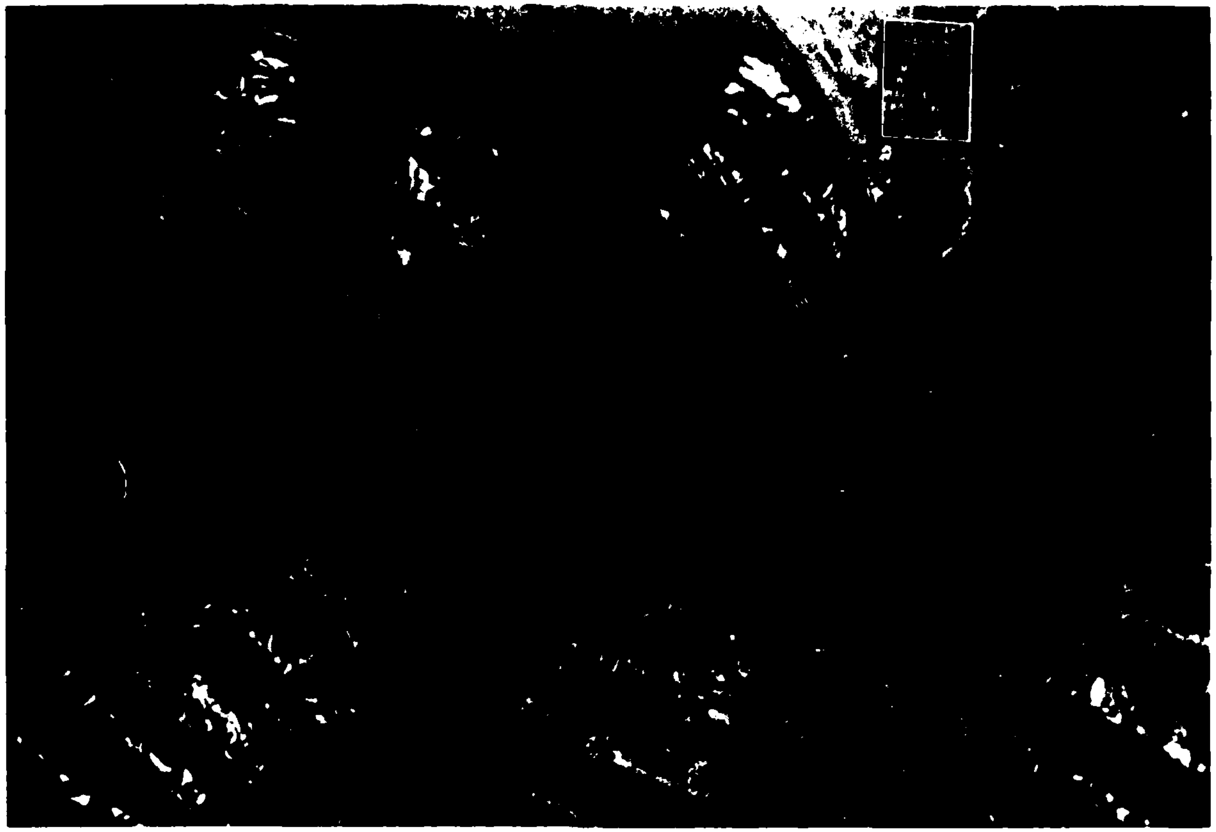
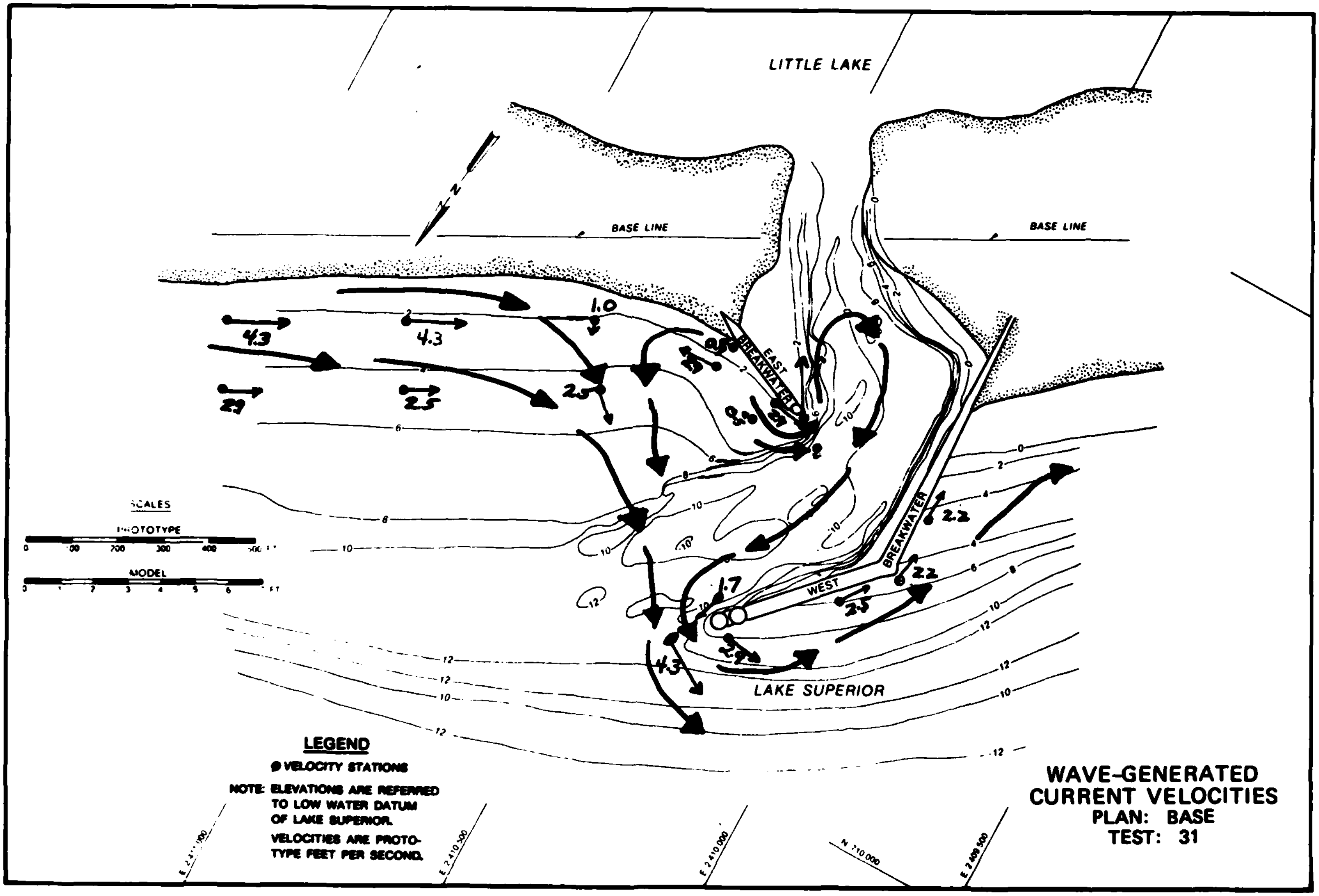

LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 30

PLATE 89



CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 31

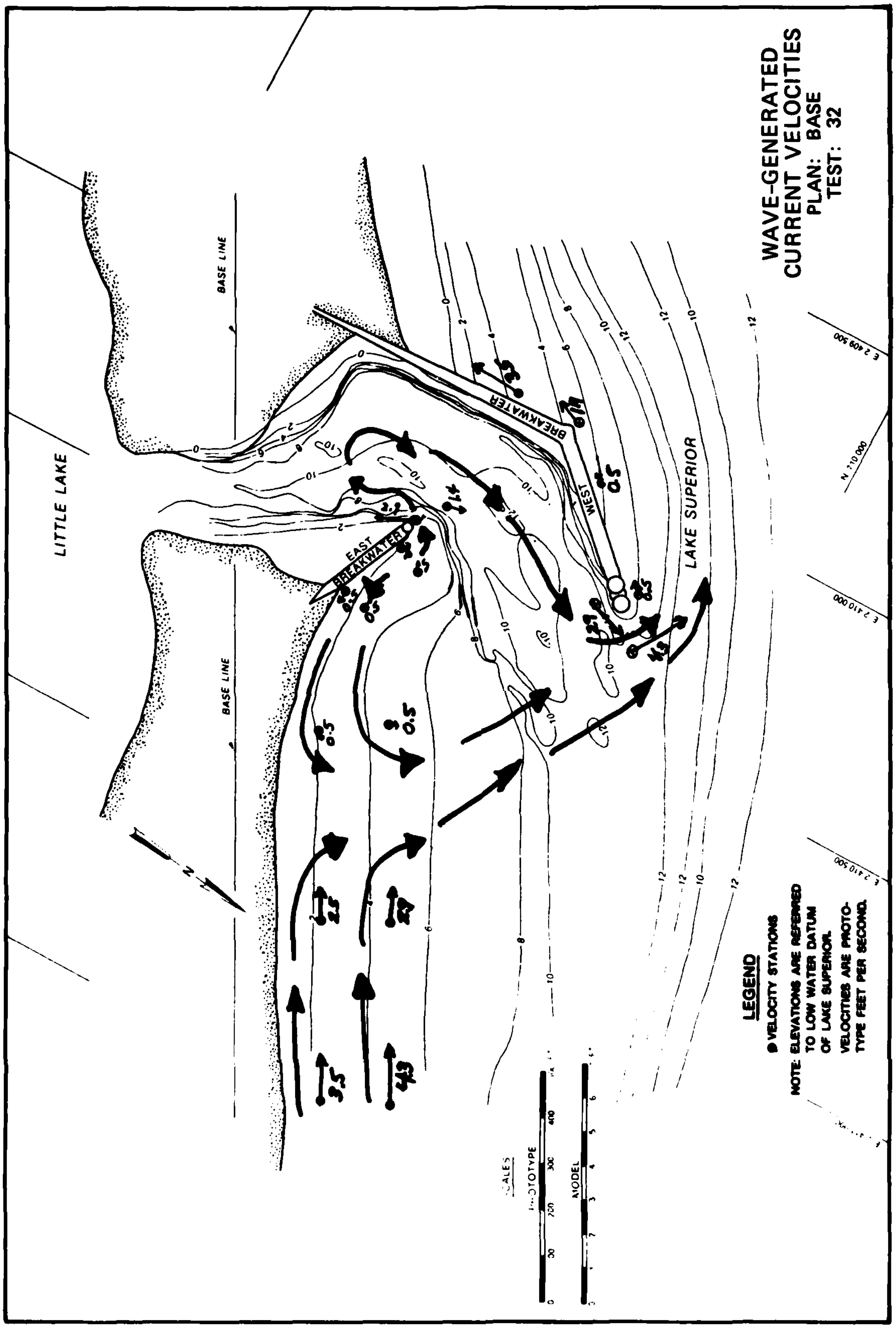


LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
N
SCALES
PROTOTYPE
MODEL
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED CURRENT VELOCITIES
PLAN: BASE
TEST: 31

CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 5 ft
SEICHE HEIGHT 0

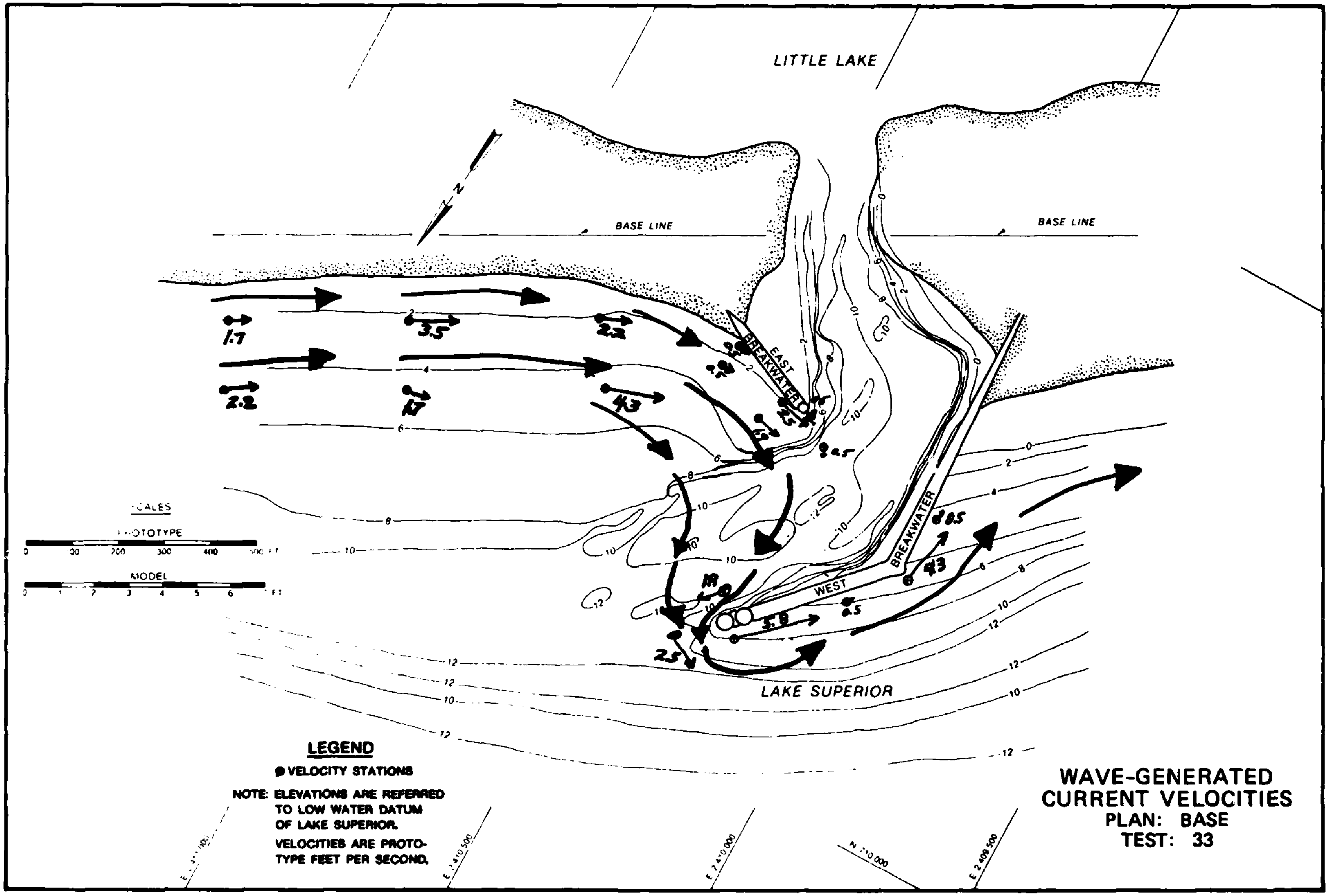
SHOALING TEST 32

PLATE 92


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 32
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
MODEL

CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 33


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 33
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 34

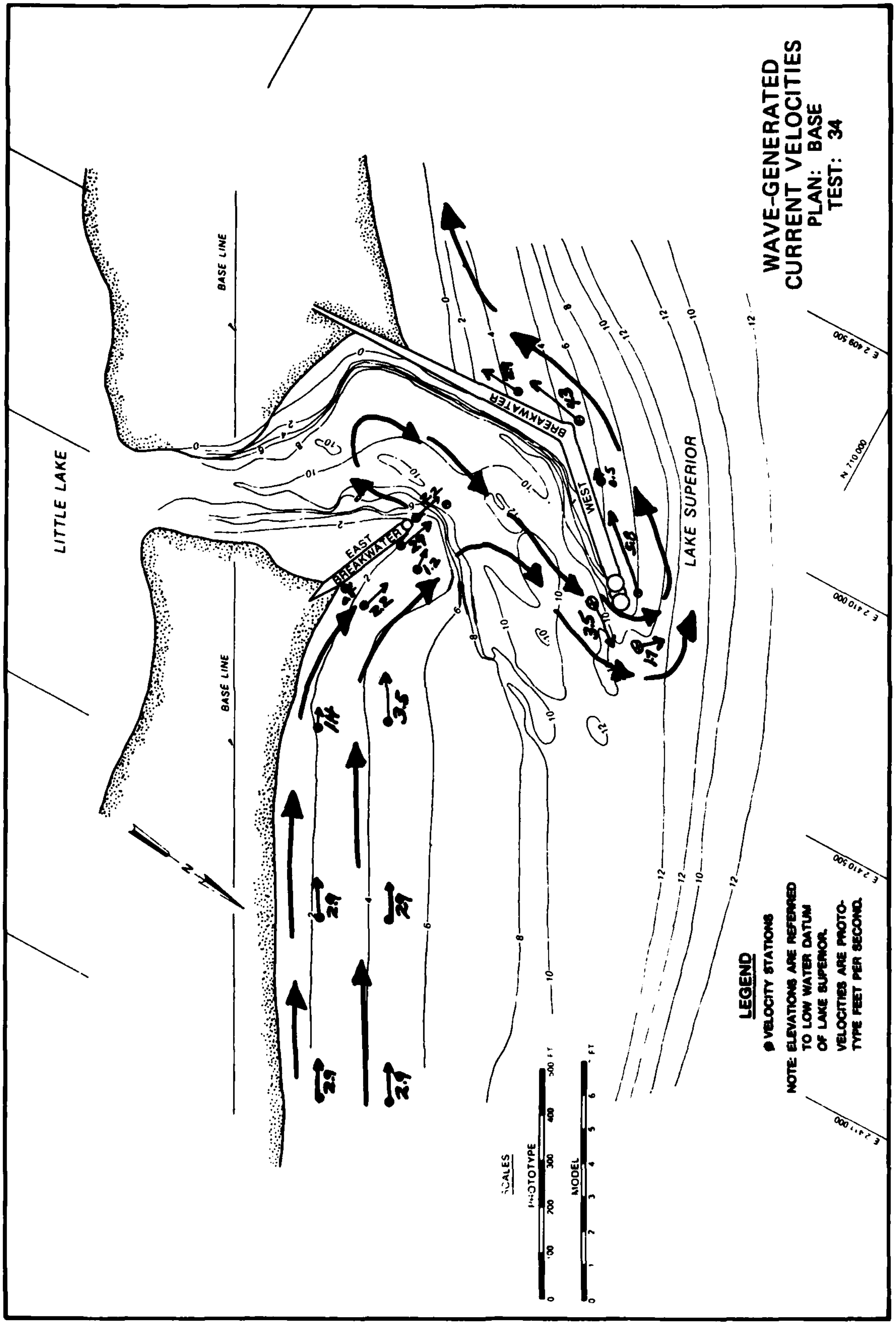

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 34
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
N 710 000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 97

CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 9 sec
WAVE HEIGHT 16 ft
SEICHE HEIGHT 0

SHOALING TEST 35

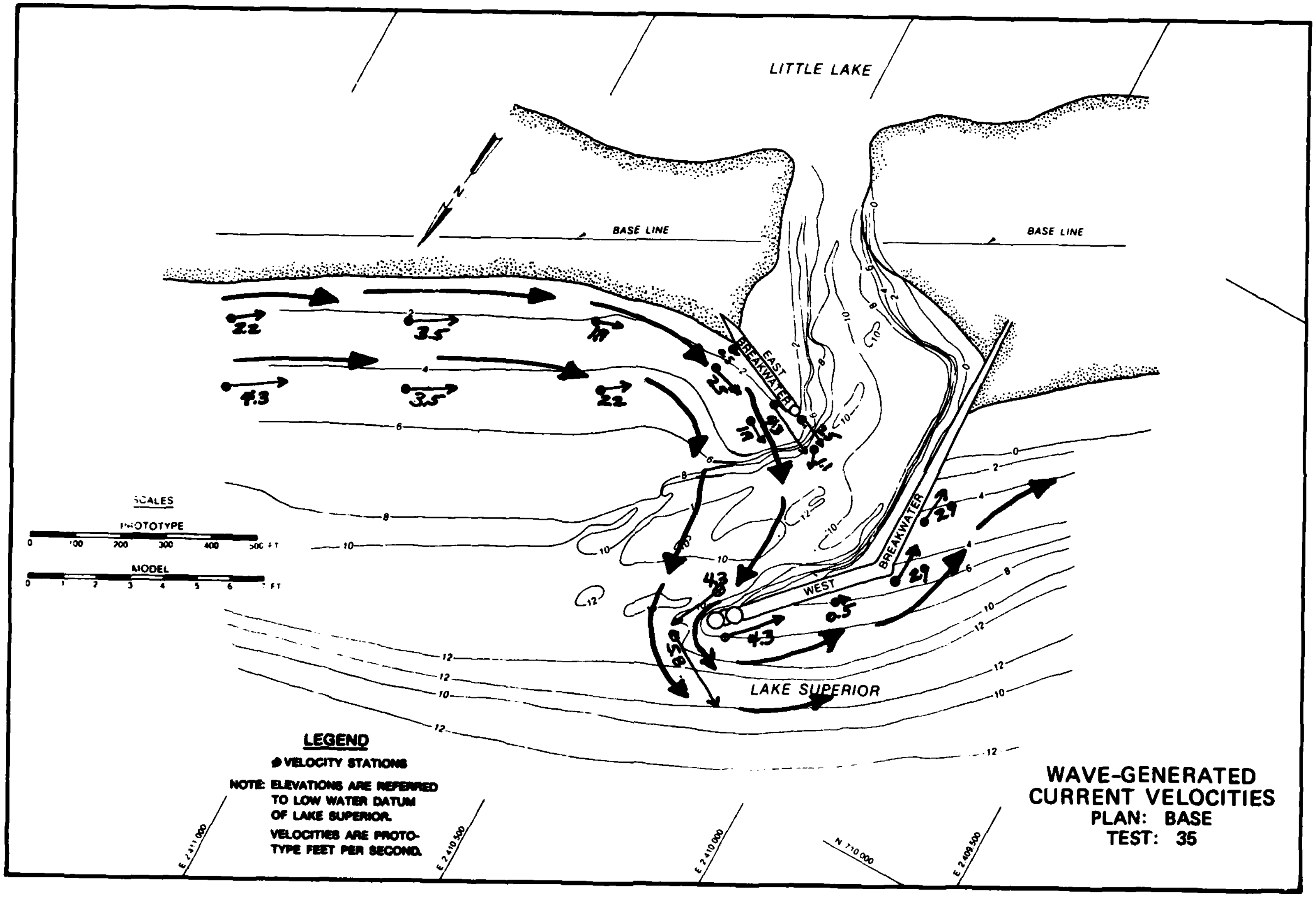
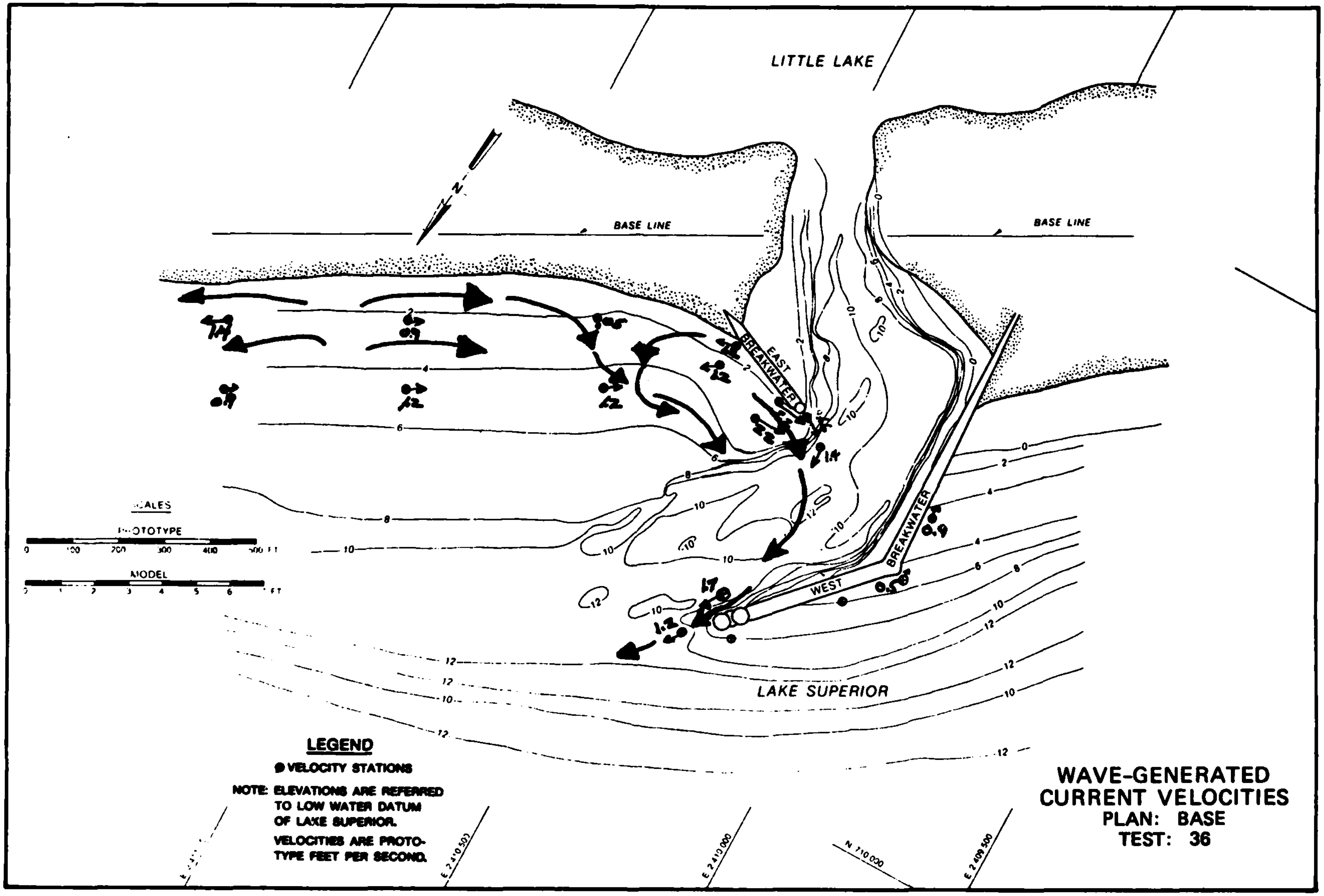
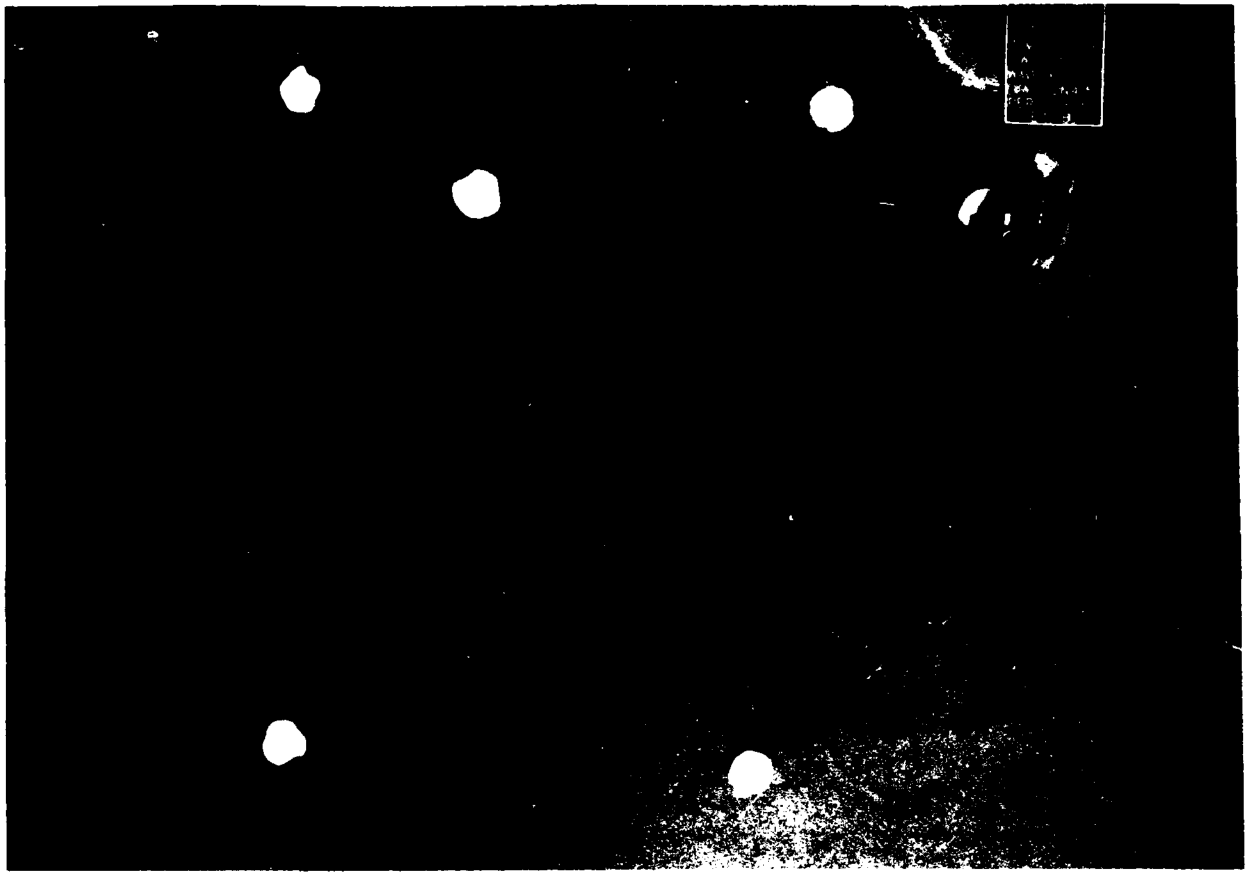

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 35
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2 411 000
E 2 410 500
E 2 410 000
E 2 409 500
N 710 000

PLATE 99

CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

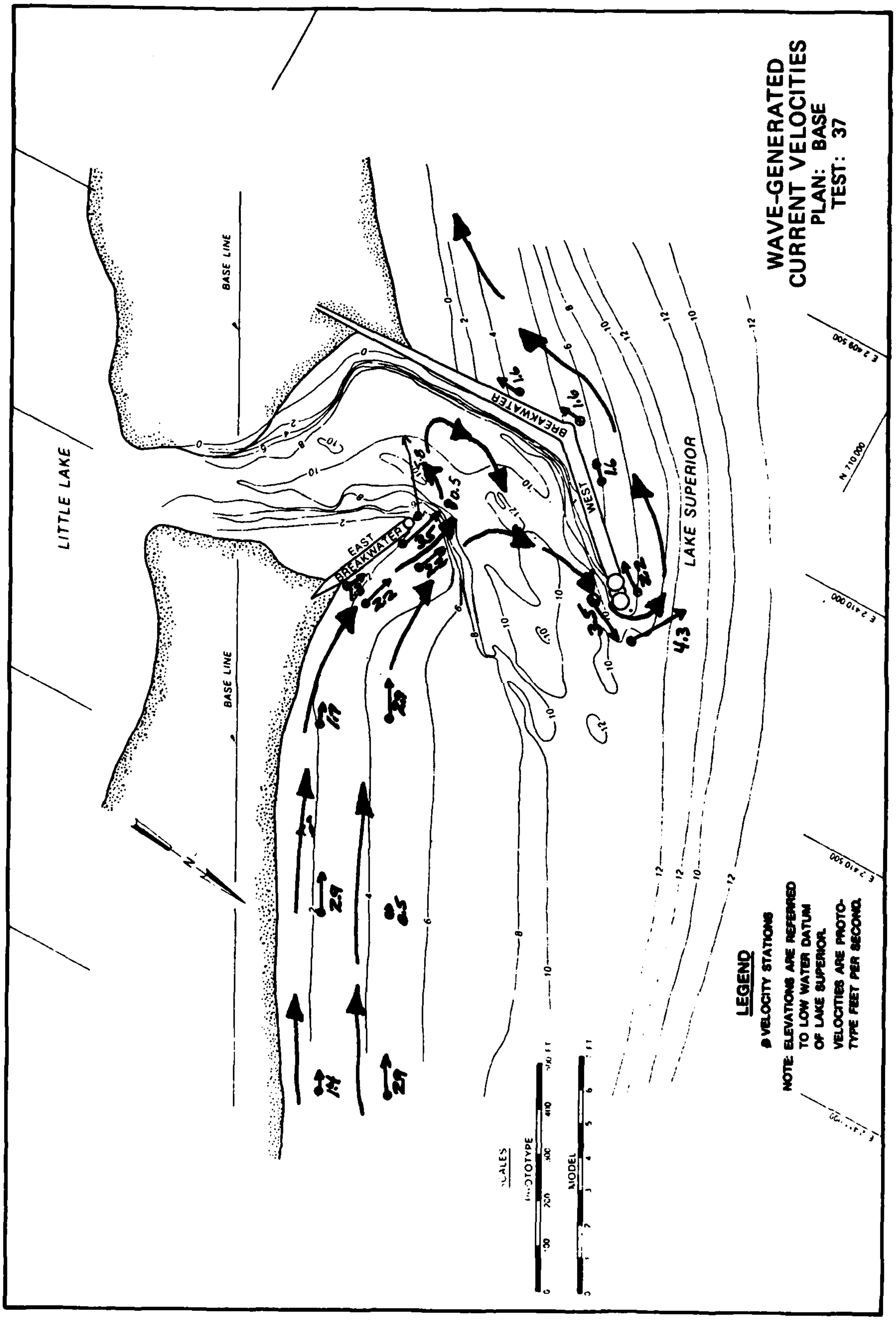
SHOALING TEST 36


LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 36



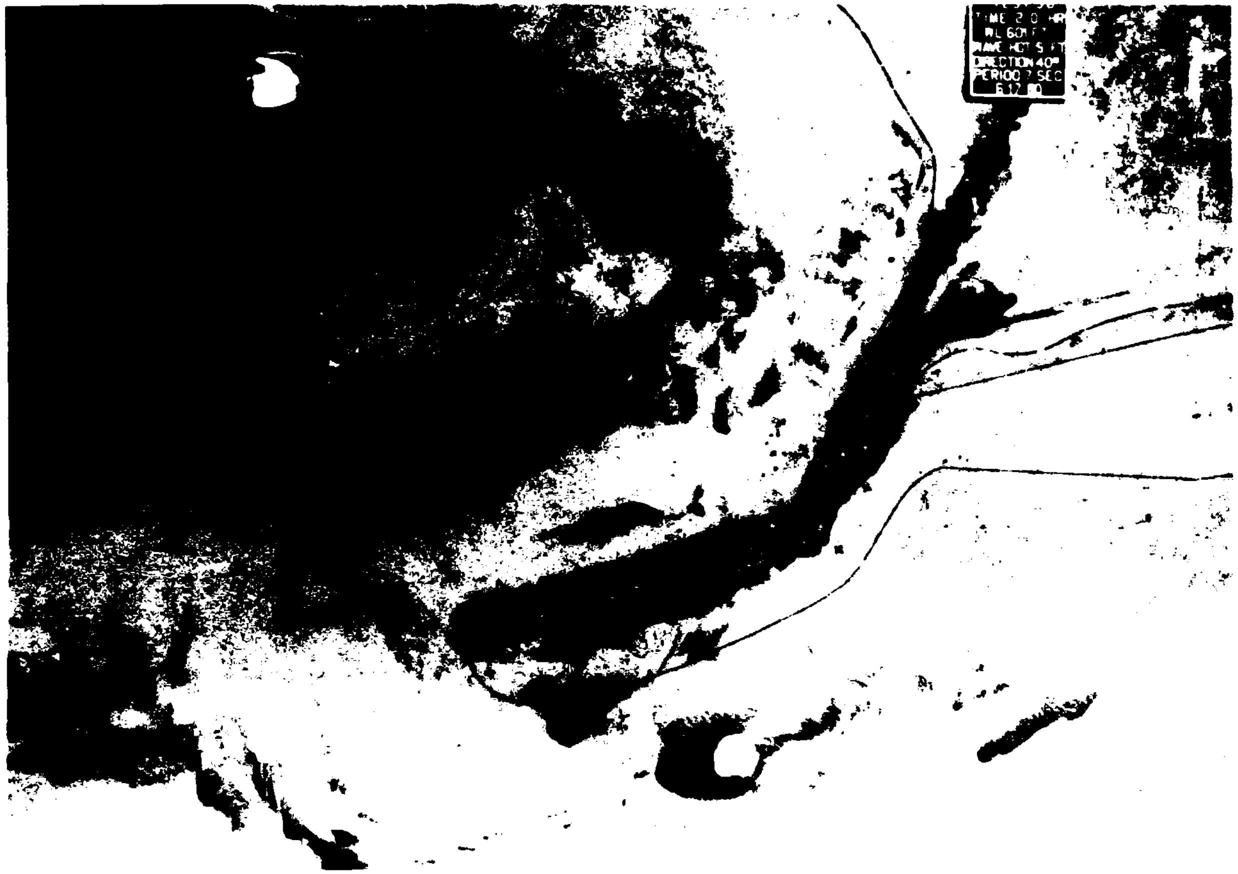
CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 37



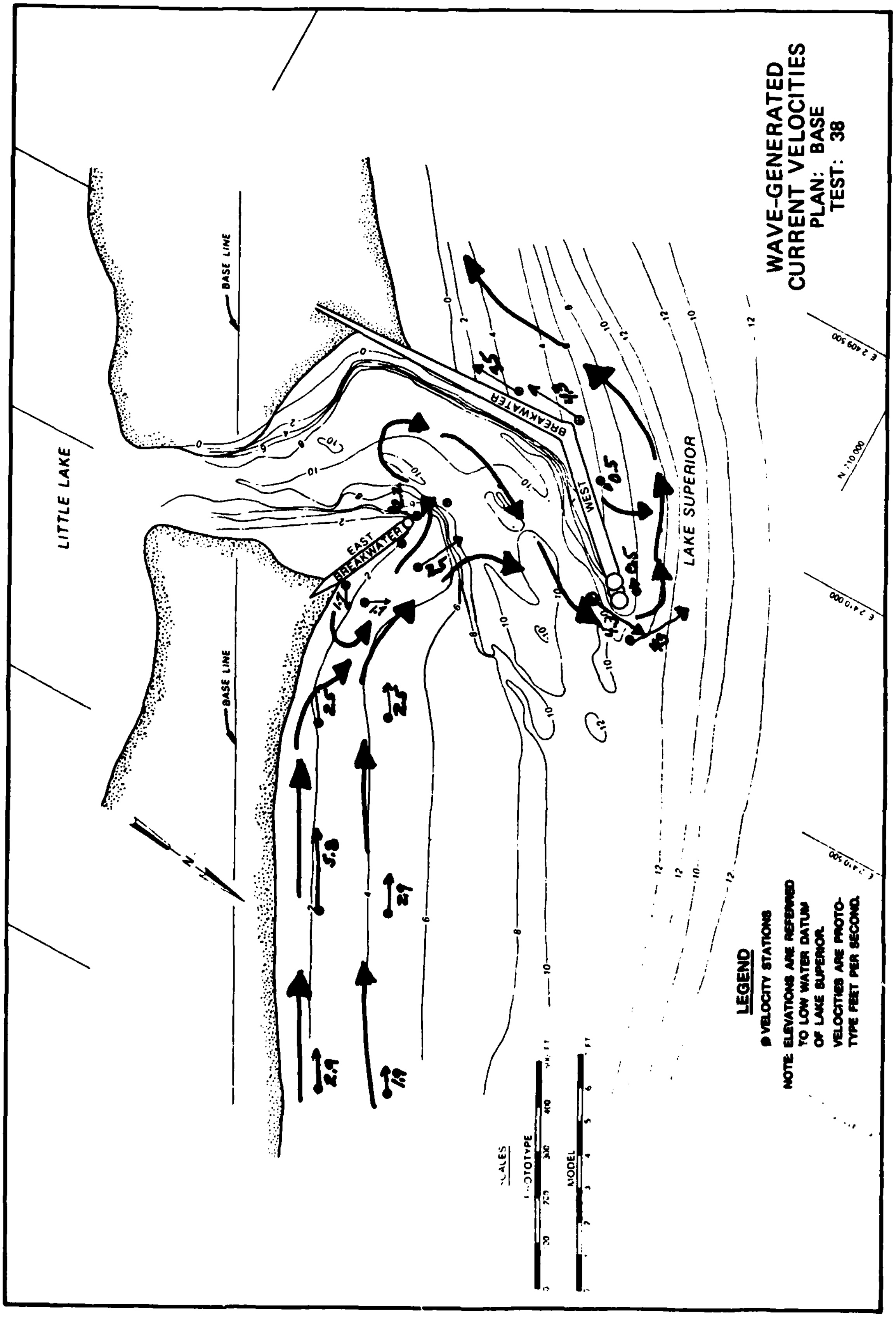
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 37
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
N 710,000
E 2,409,500
E 2,410,000
E 2,410,500
4.3
1.6
1.6
1.6
0.5
2.2
2.9

PLATE 103



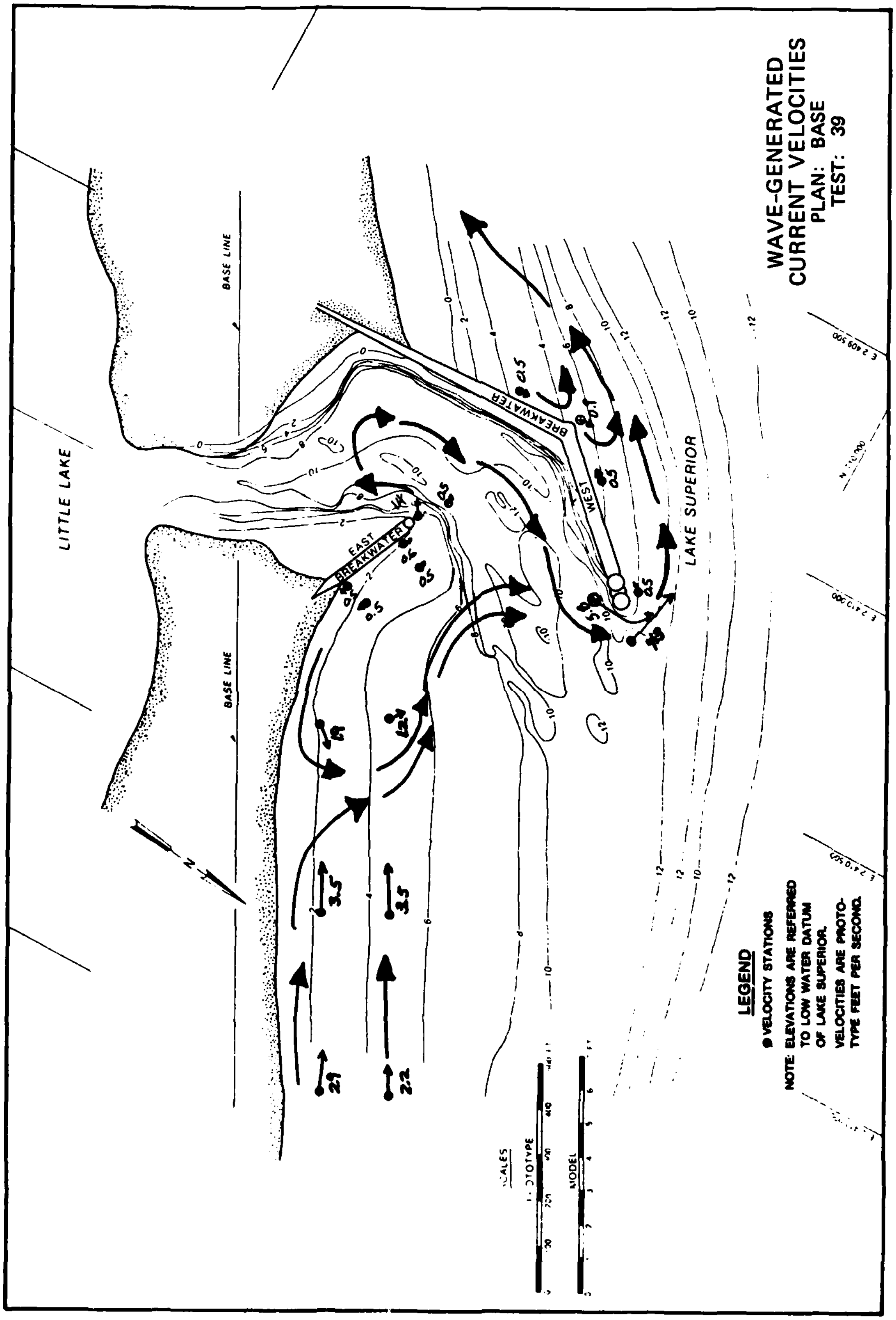
CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 7 sec
WAVE HEIGHT 5 ft
SEICHE HEIGHT 0

SHOALING TEST 38


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 38
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
MODEL

CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 39

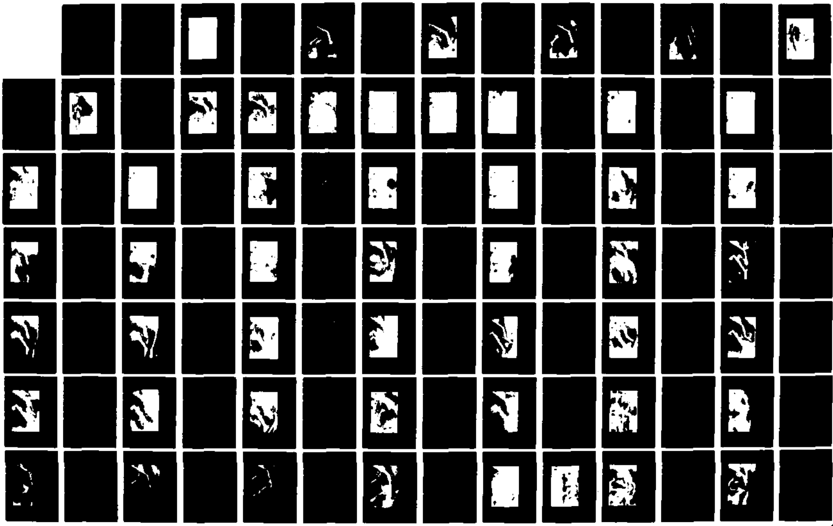

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 39
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
MODEL

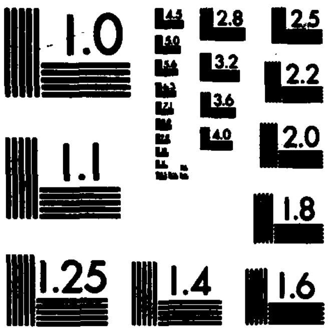
CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

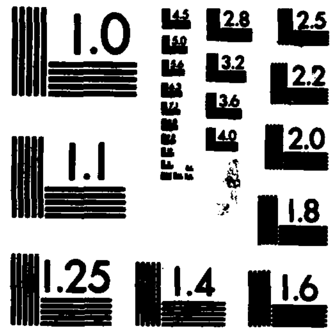
SHOALING TEST 40

AD-A120 776 PREVENTION OF SHOALING AT LITTLE LAKE HARBOR MICHIGAN HYDRAULIC MODEL INV..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 3/4

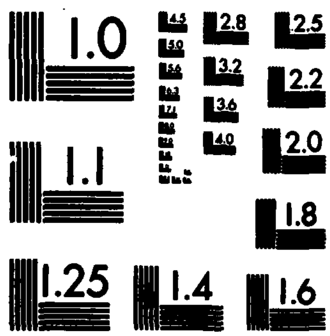
UNCLASSIFIED W C SEABERGH ET AL. JUL 82 WES/TR/HL-82-16 F/G 13/2 NL



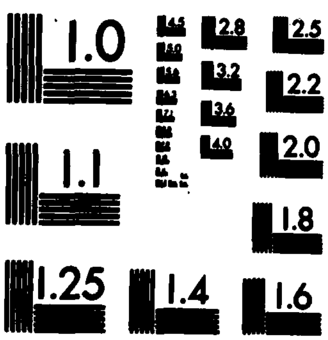




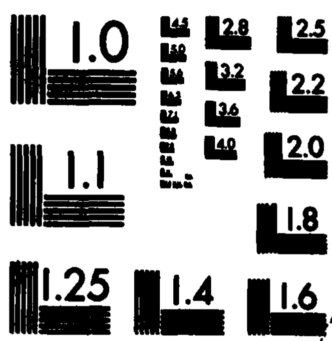
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



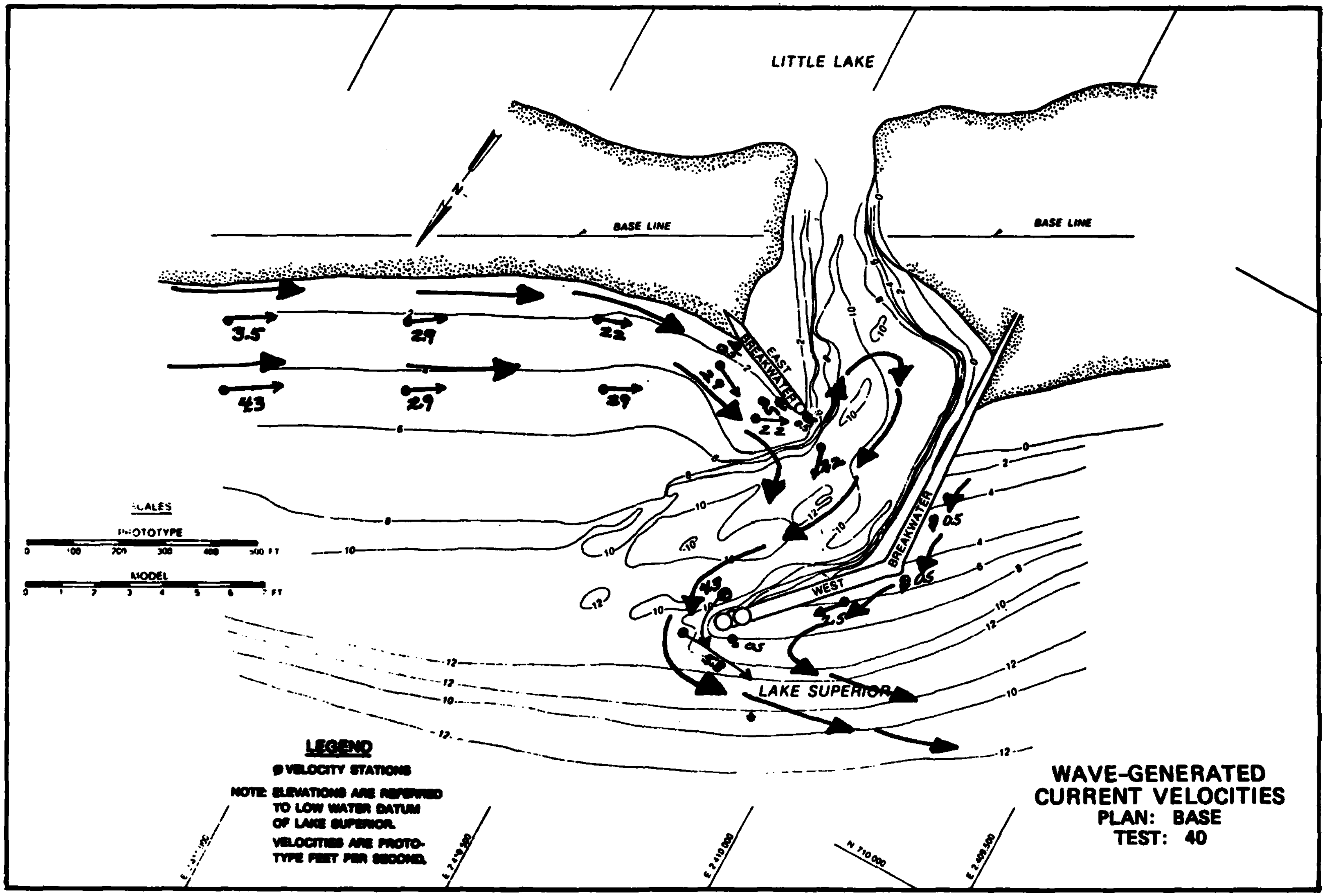
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



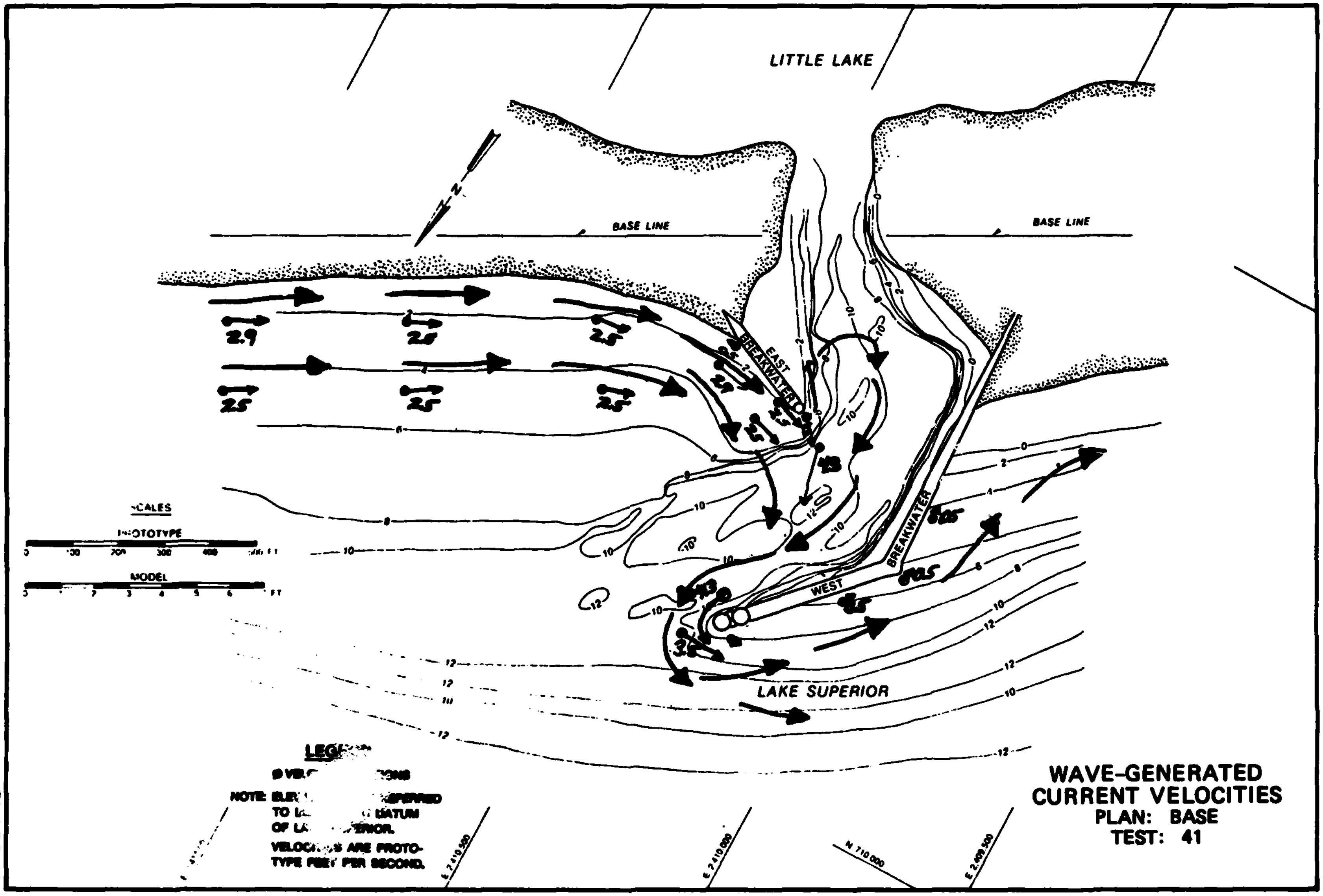
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
MODEL
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED CURRENT VELOCITIES
PLAN: BASE
TEST: 40

CONDITION Base
WAVE DIRECTION 40°
WAVE PERIOD 9 sec
WAVE HEIGHT 16 ft
SEICHE HEIGHT 0

SHOALING TEST 41



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 41

PLATE 111

CONDITION Base
WAVE DIRECTION 359°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0

SHOALING TEST 42

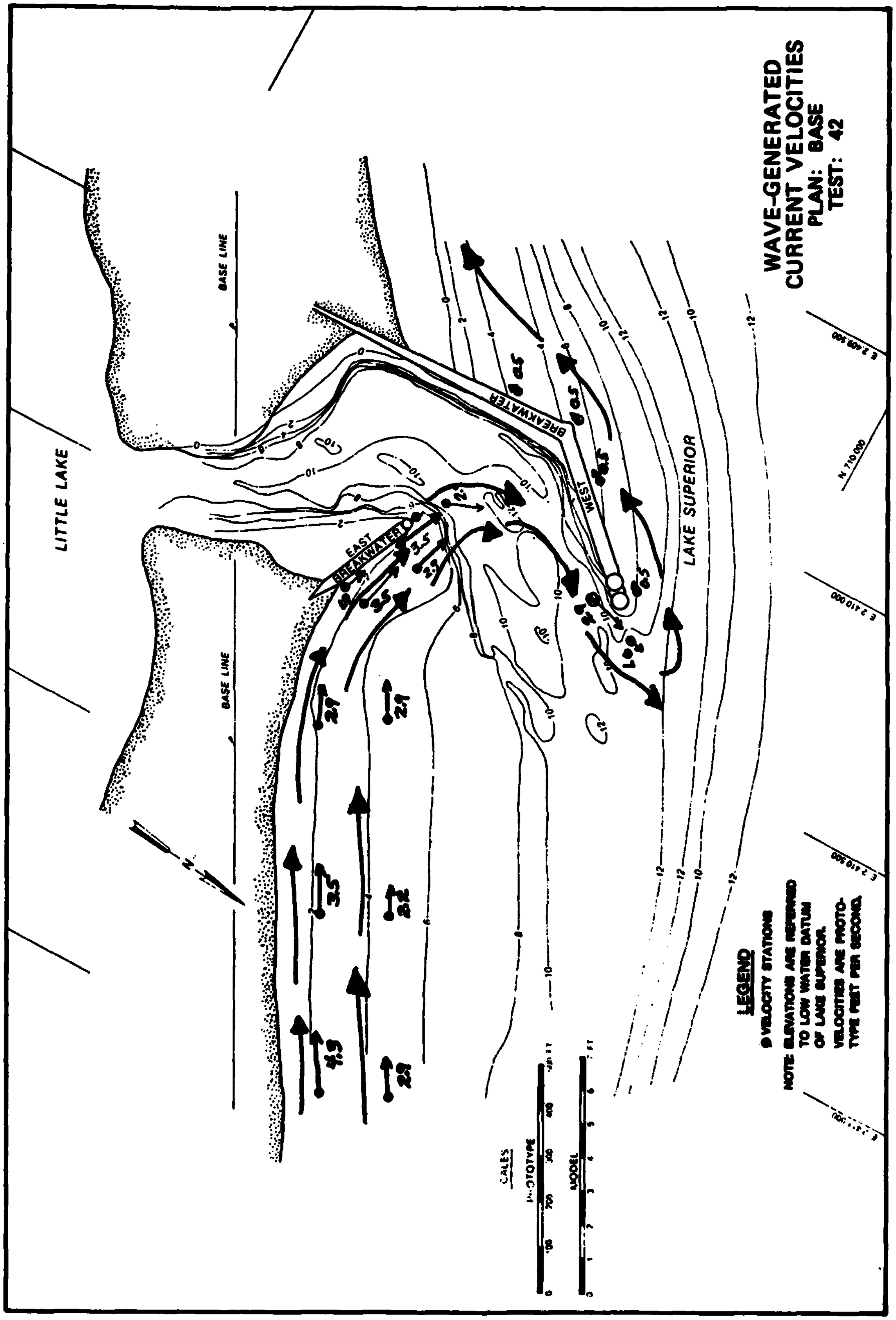

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 42
LITTLE LAKE
LAKE SUPERIOR
EAST
BREAKWATER
WEST
BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 113

CONDITION Base
WAVE DIRECTION 359°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 43

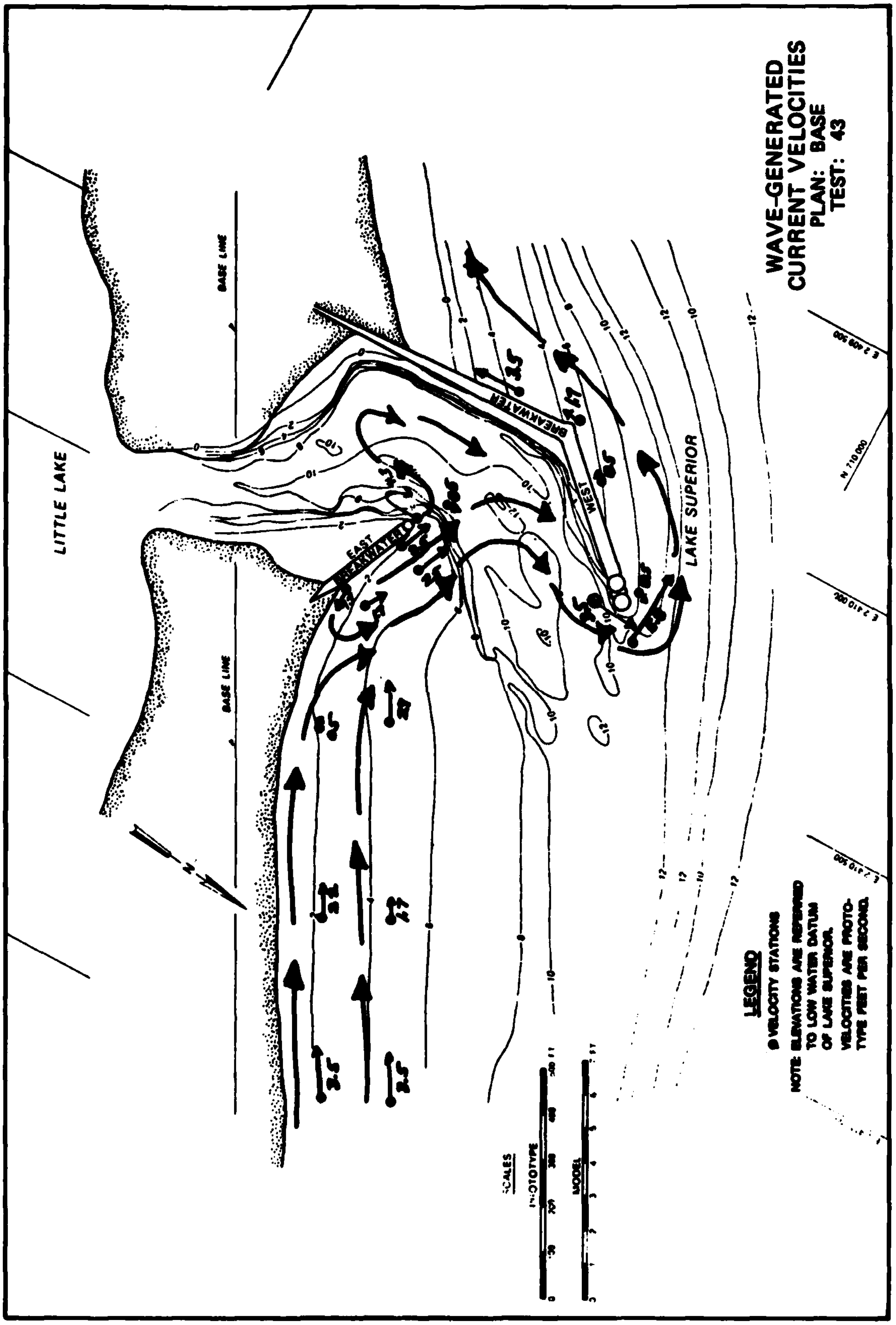
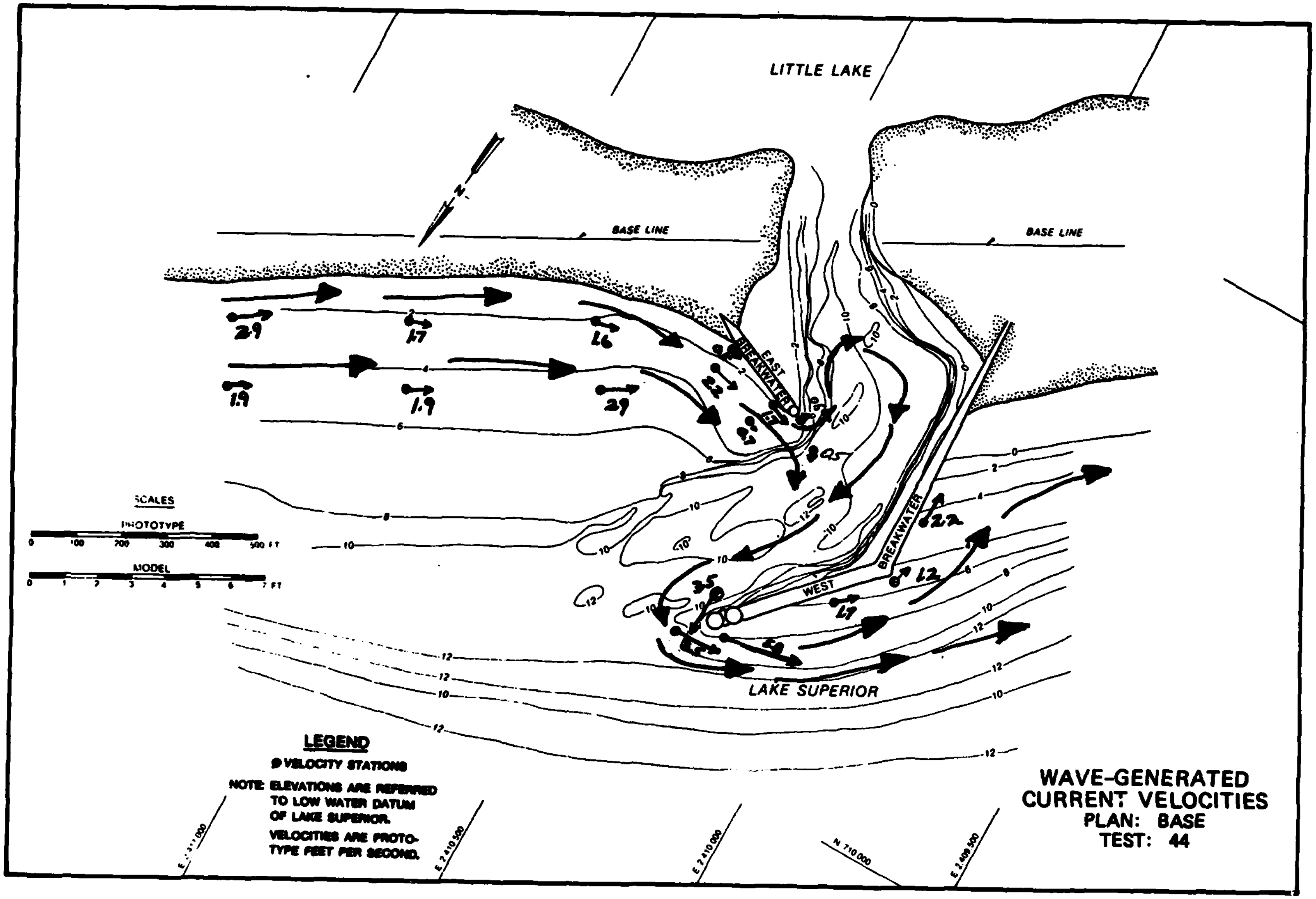

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 43
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 115

CONDITION Base
WAVE DIRECTION 359°
WAVE PERIOD 7 sec
WAVE HEIGHT 6 ft
SEICHE HEIGHT 0

SHOALING TEST 44



LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED CURRENT VELOCITIES
PLAN: BASE
TEST: 44

PLATE 117

CONDITION Base
WAVE DIRECTION 359°
WAVE PERIOD 7 sec
WAVE HEIGHT 12 ft
SEICHE HEIGHT 0

SHOALING TEST 45

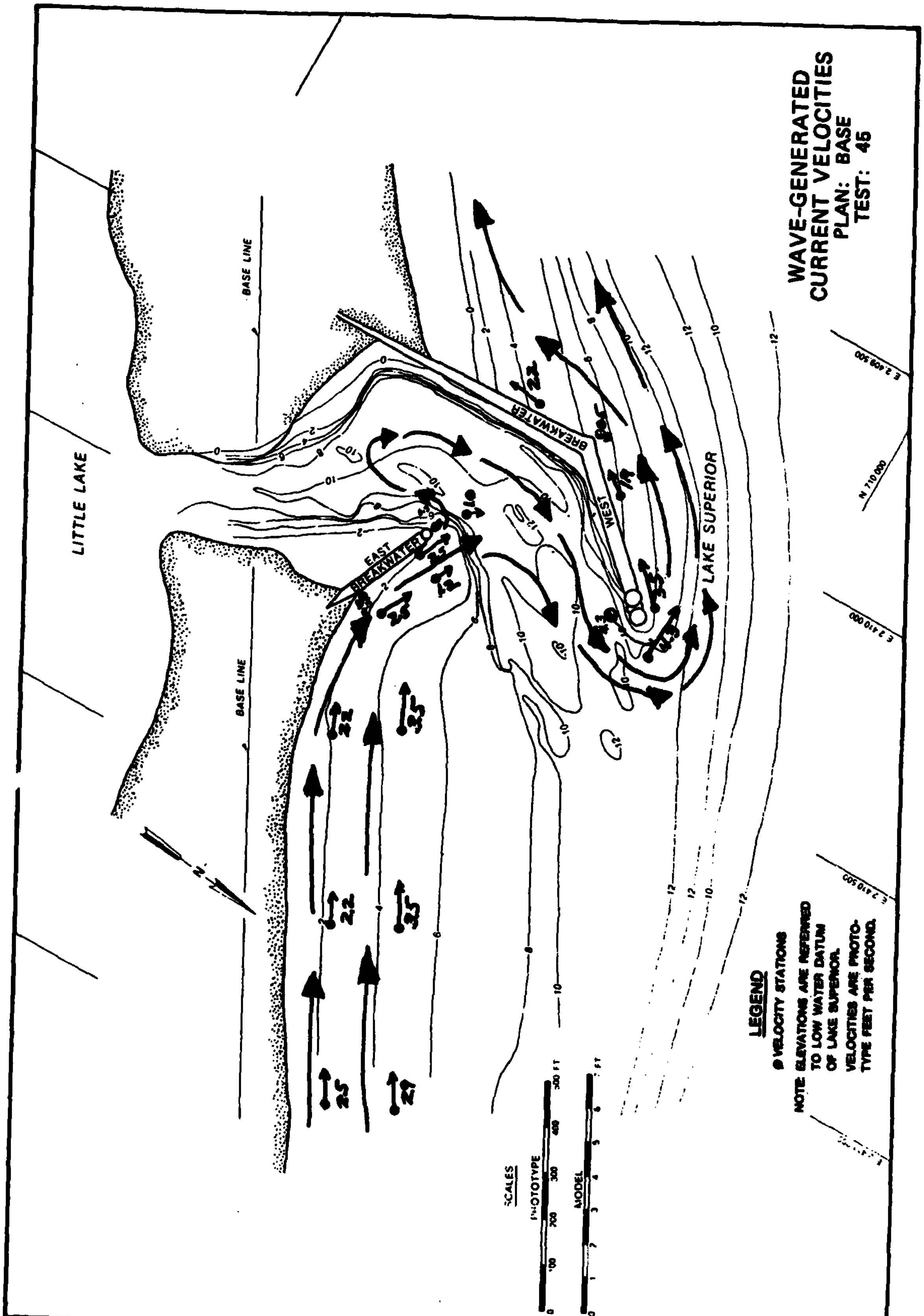
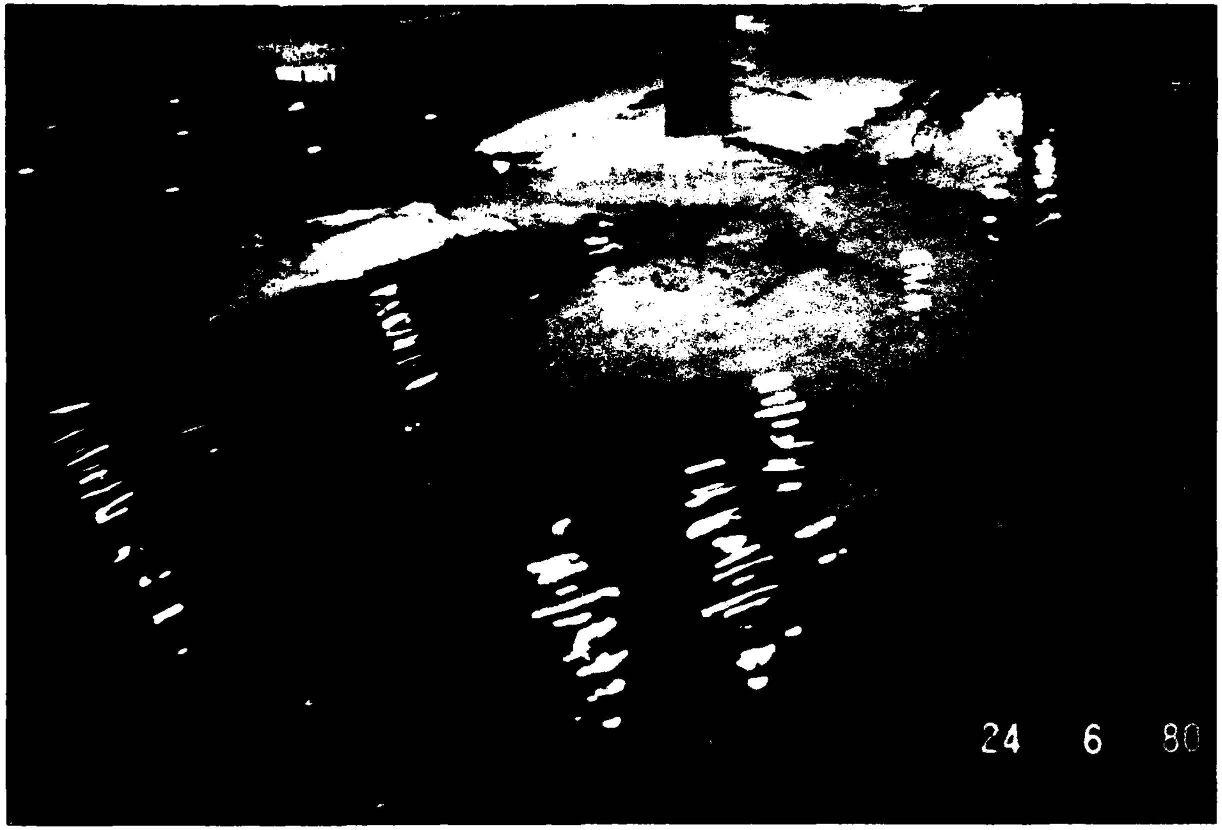
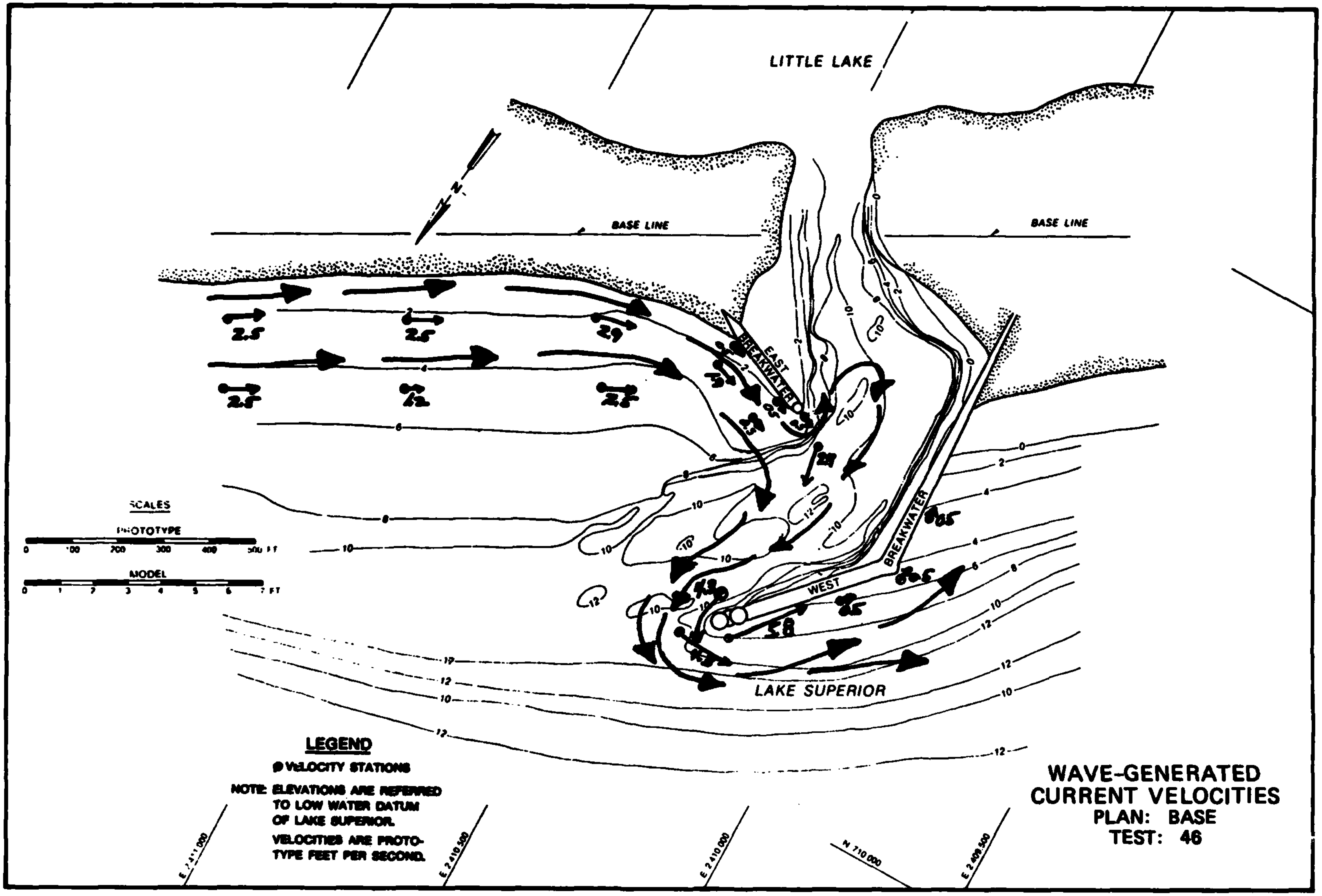

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 45
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
E 2,409,500
N 710,000
E 2,410,000
E 2,410,500
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 FT

PLATE 119



CONDITION Base
WAVE DIRECTION 359°
WAVE PERIOD 9 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 46

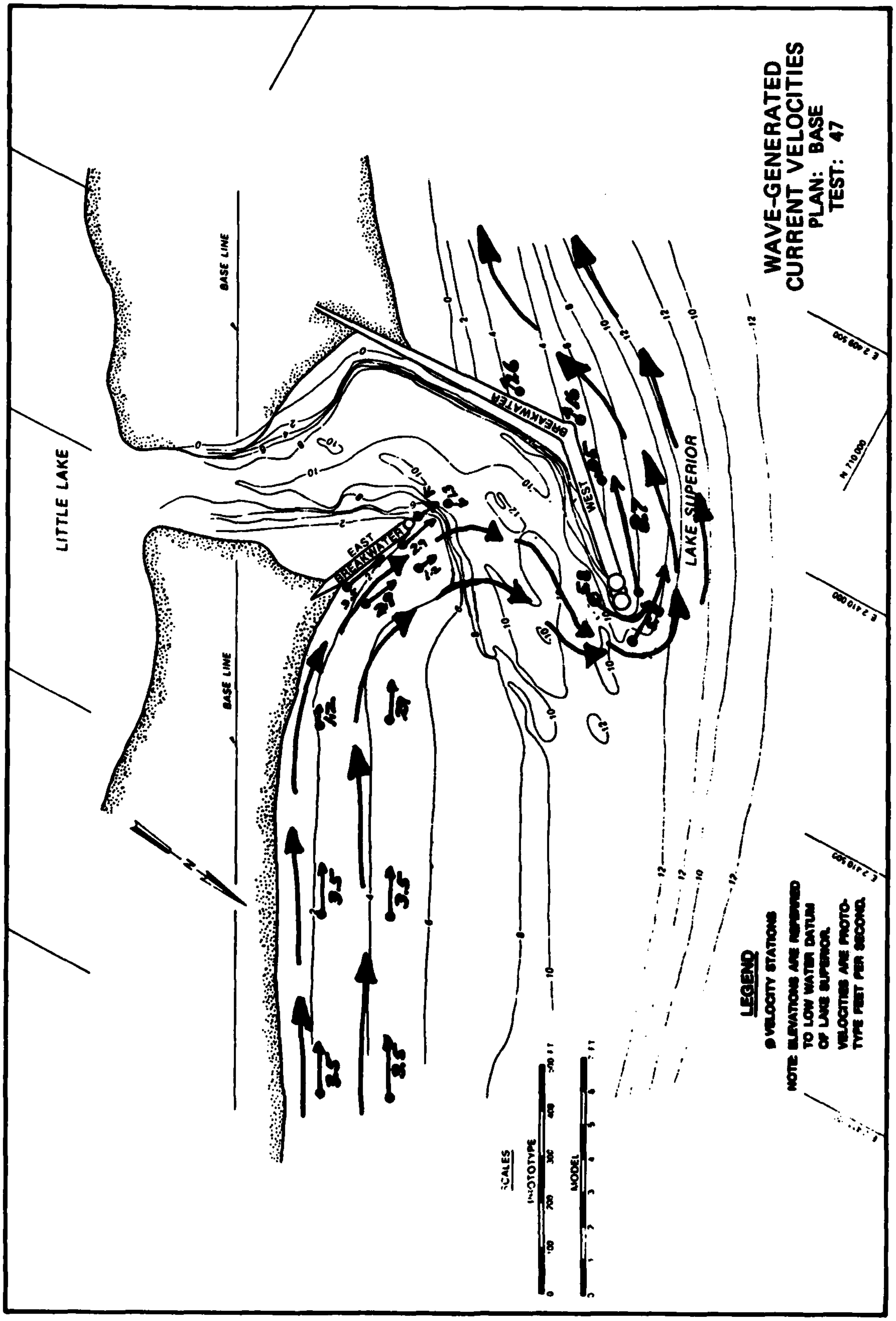


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 46

PLATE 121

CONDITION Base
WAVE DIRECTION 359°
WAVE PERIOD 9 sec
WAVE HEIGHT 21 ft
SEICHE HEIGHT 0

SHOALING TEST 47



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: BASE
TEST: 47
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
MODEL

PLATE 123

CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.2 ft

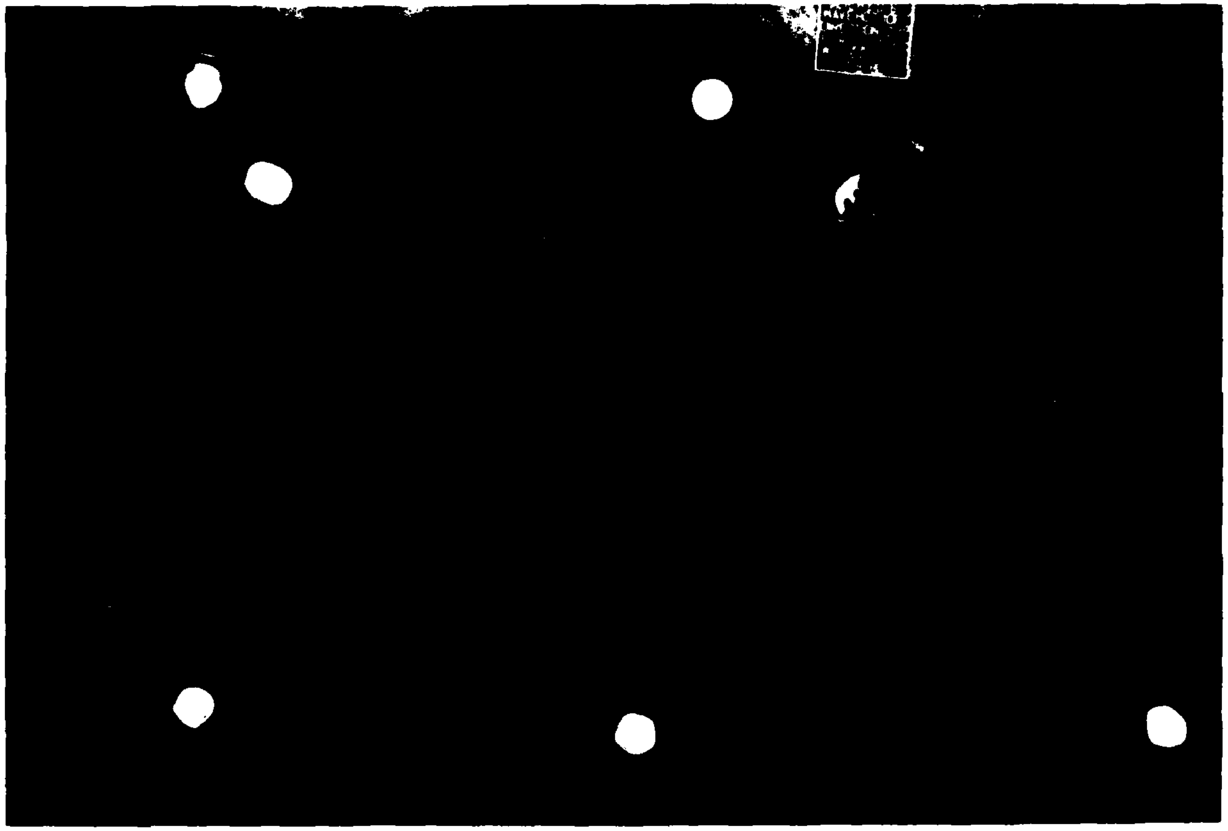
SHOALING TEST 48

CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.2 ft

SHOALING TEST 49

CONDITION Base
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.6 ft

SHOALING TEST 50

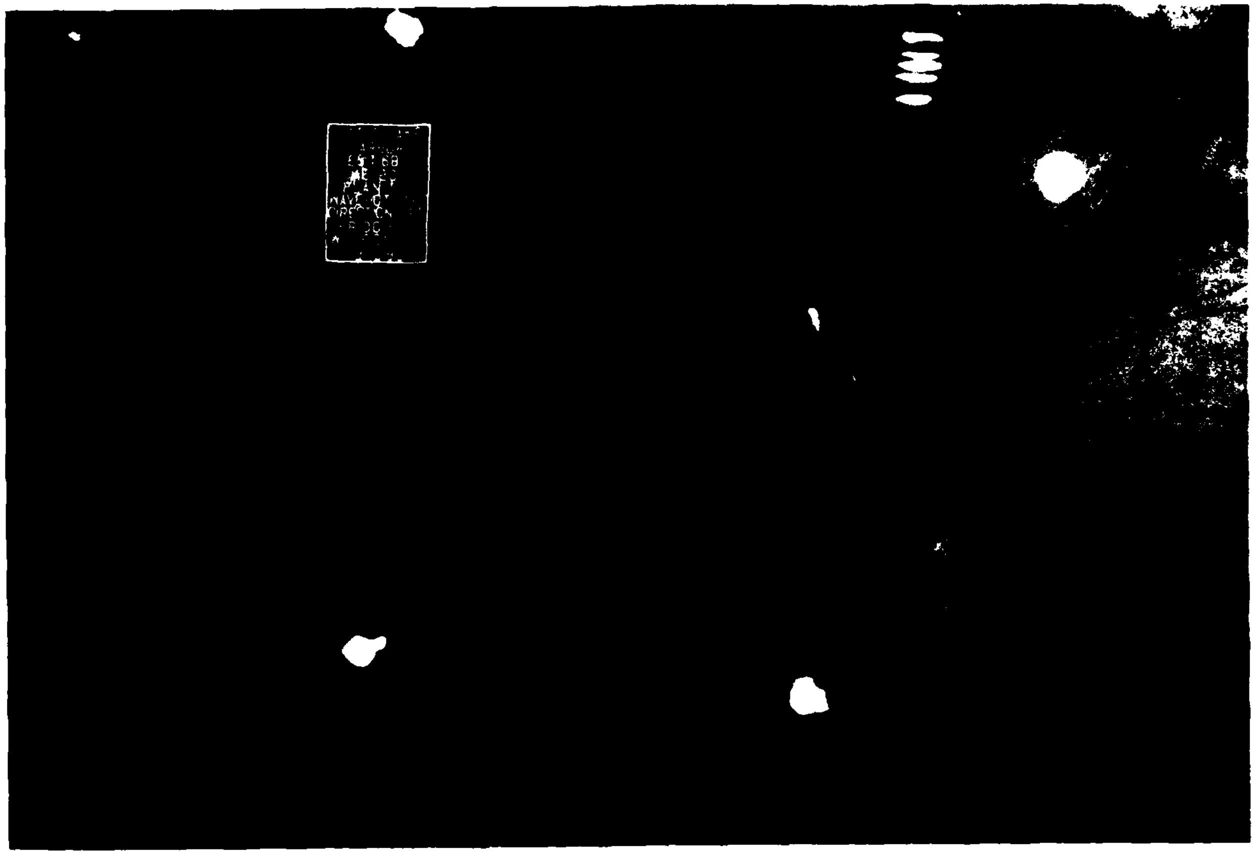


CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.6 ft

SHOALING TEST 51

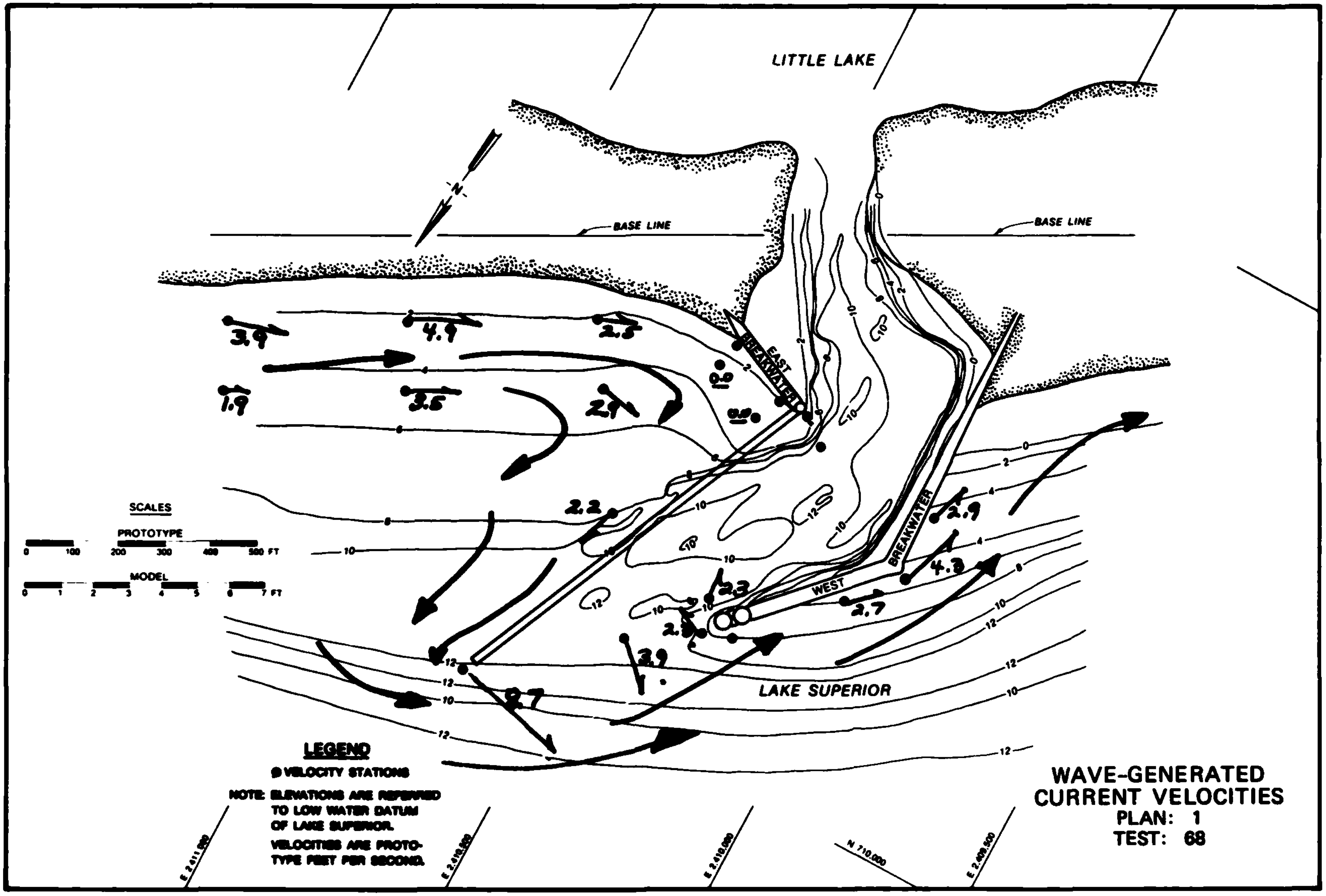
CONDITION Base
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0.6 ft

SHOALING TEST 52



CONDITION Plan 1
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 68



WAVE-GENERATED CURRENT VELOCITIES
PLAN: 1
TEST: 68

PLATE 130

CONDITION Plan 1
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 69

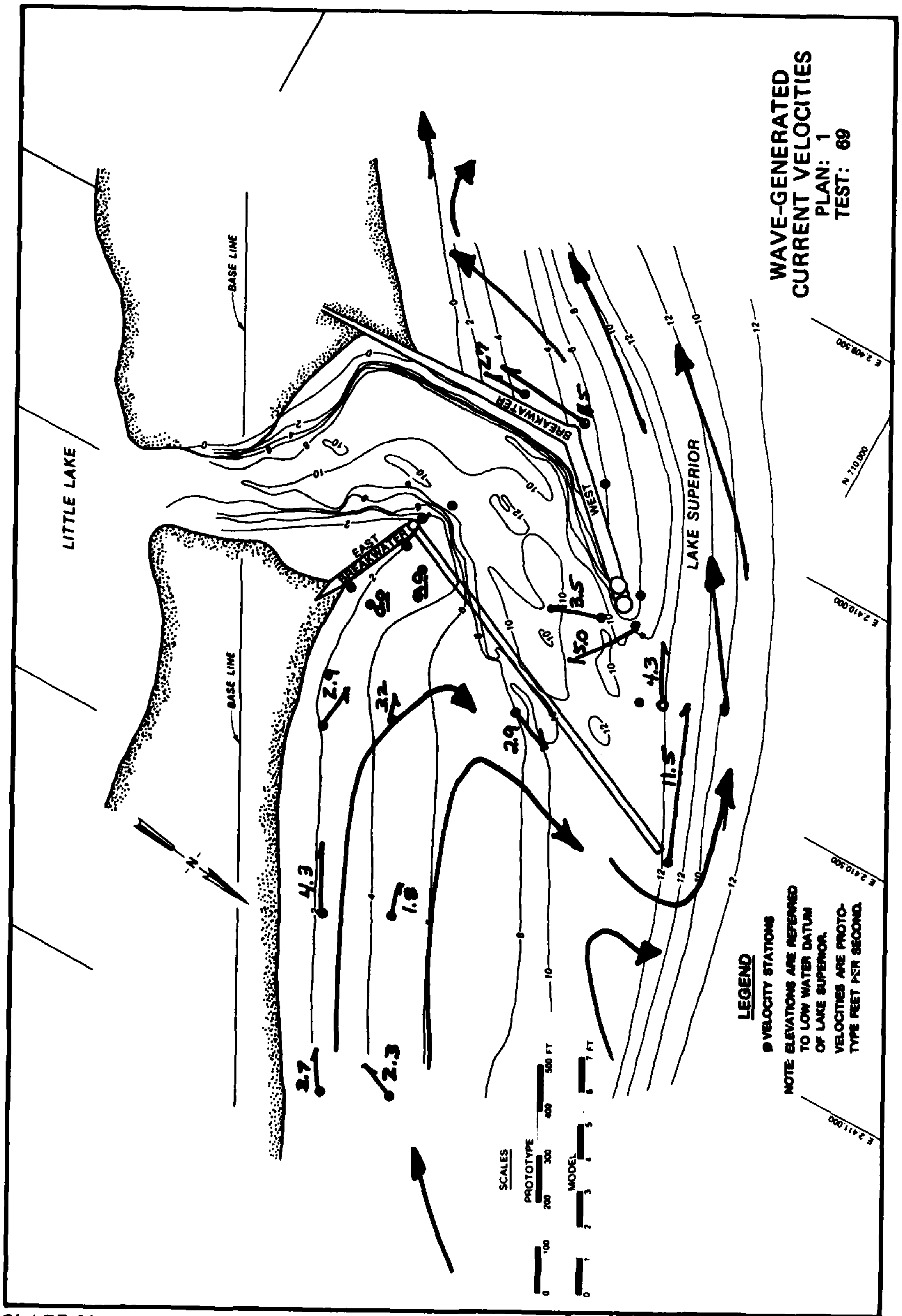
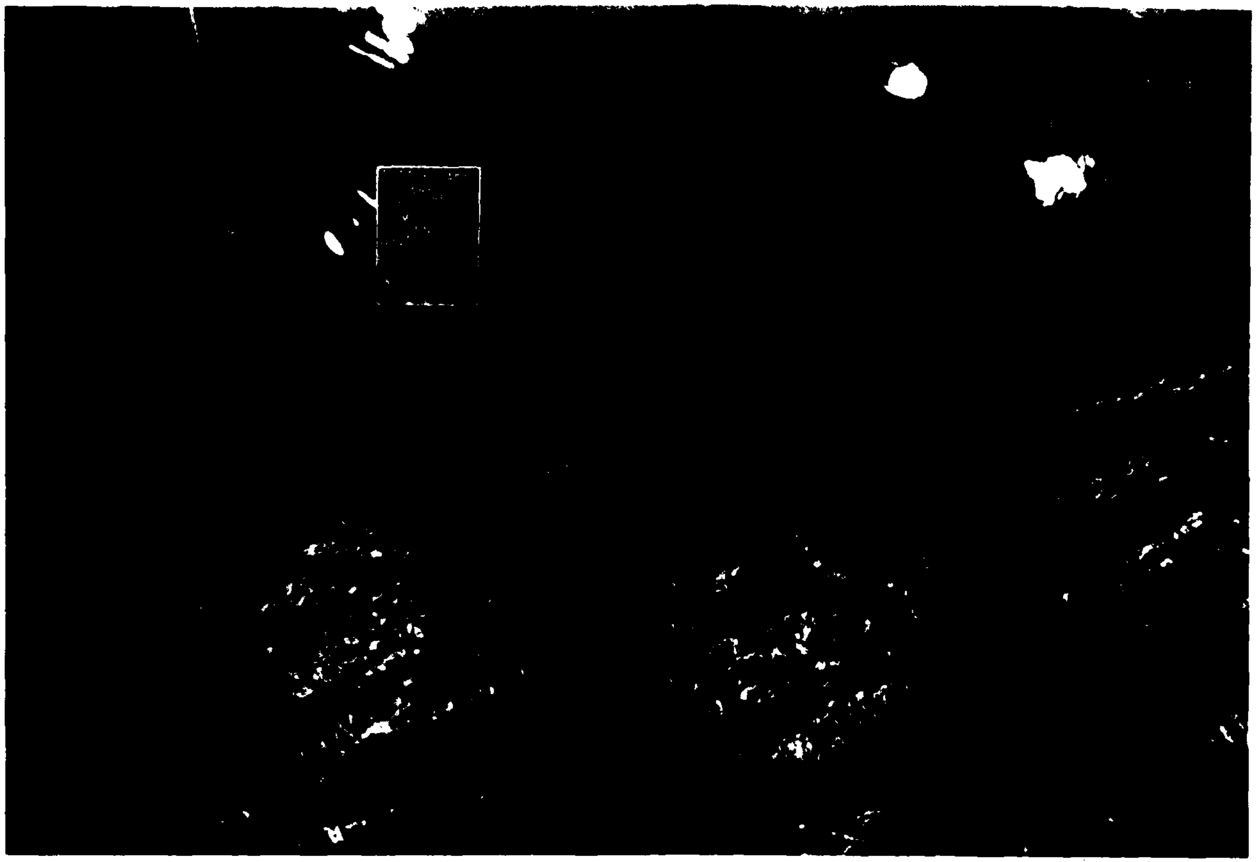
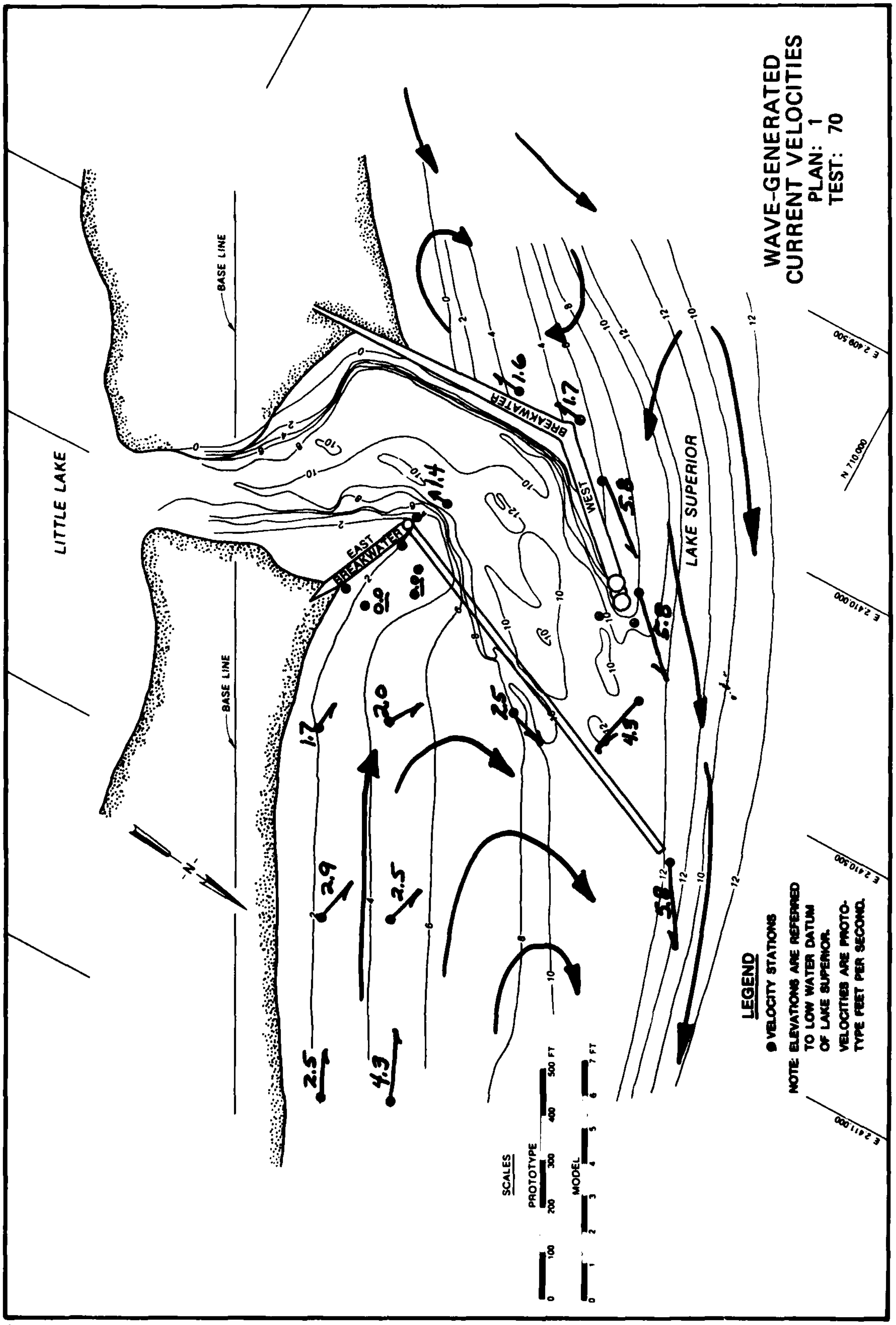

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1
TEST: 69
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
E 2,408,500
N 710,000
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 132



CONDITION Plan 1
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 70



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1
TEST: 70
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
WEST BREAKWATER
EAST BREAKWATER
N
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2,409,500
E 2,410,000
E 2,410,500
E 2,411,000
N 710,000
1.6
1.7
1.4
5.8
5.8
4.3
5.8
0.0
0.0
1.7
2.0
2.5
2.9
2.5
2.5
4.3

PLATE 134

CONDITION Plan 1
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 71

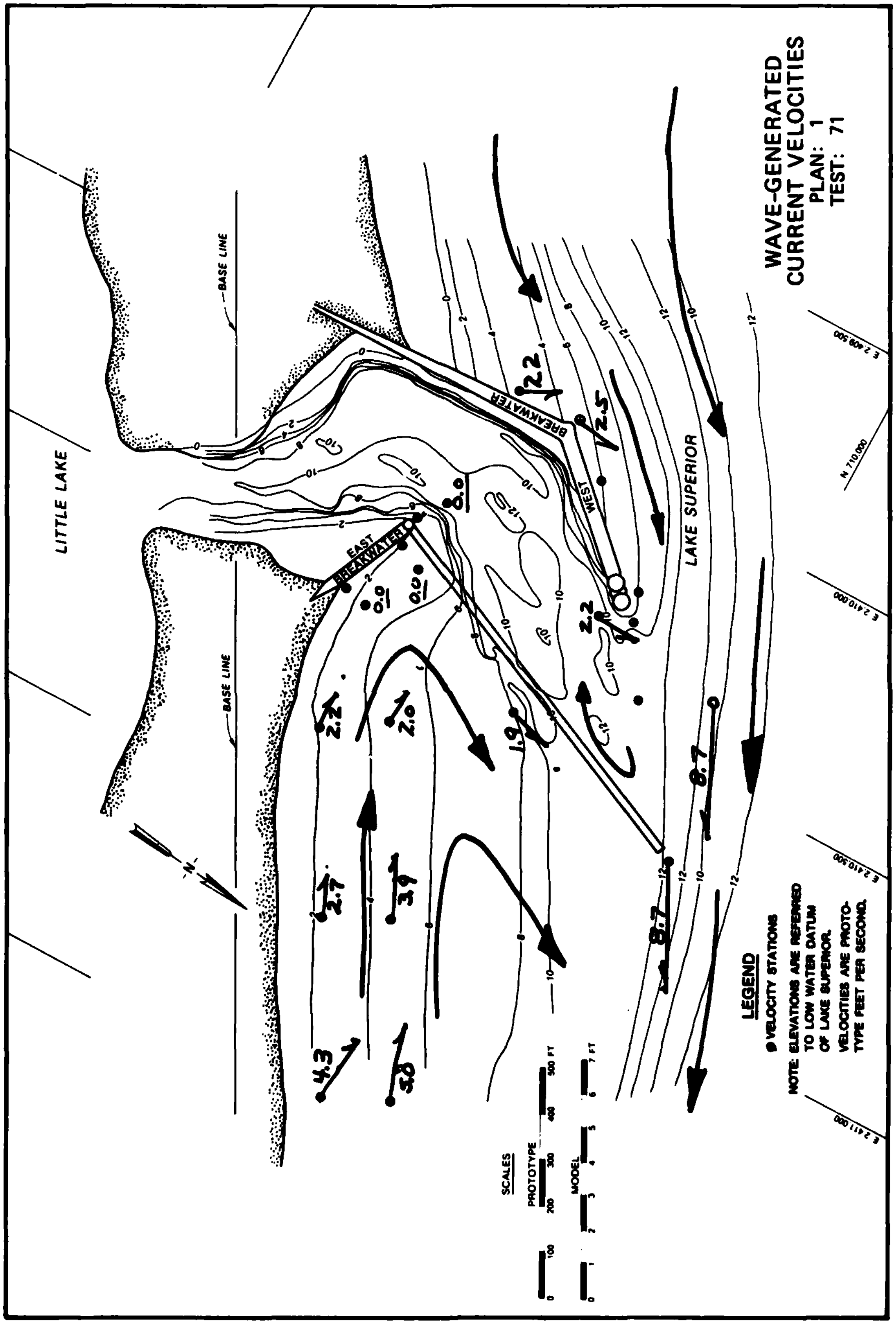
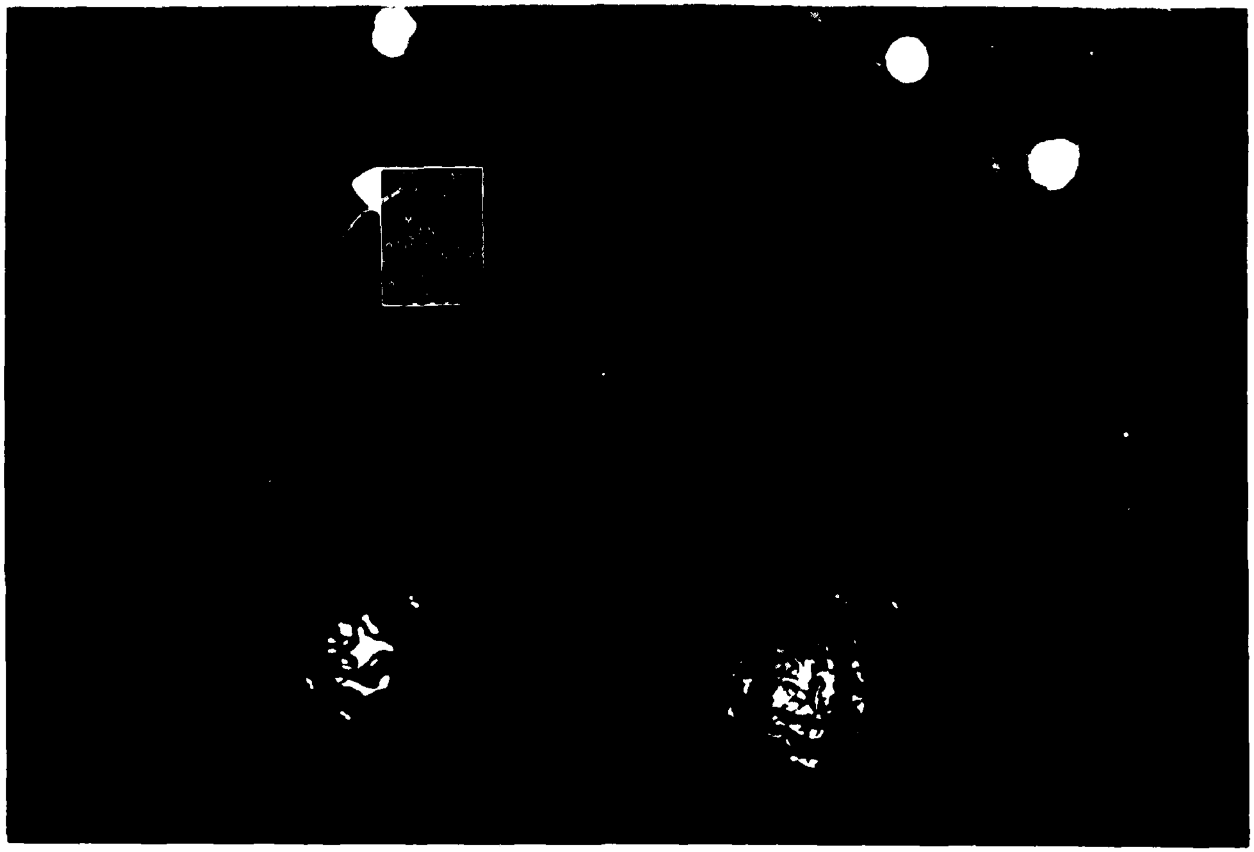

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1
TEST: 71
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
E 2,409,500
N 710,000
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 136



CONDITION Plan 1
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 72

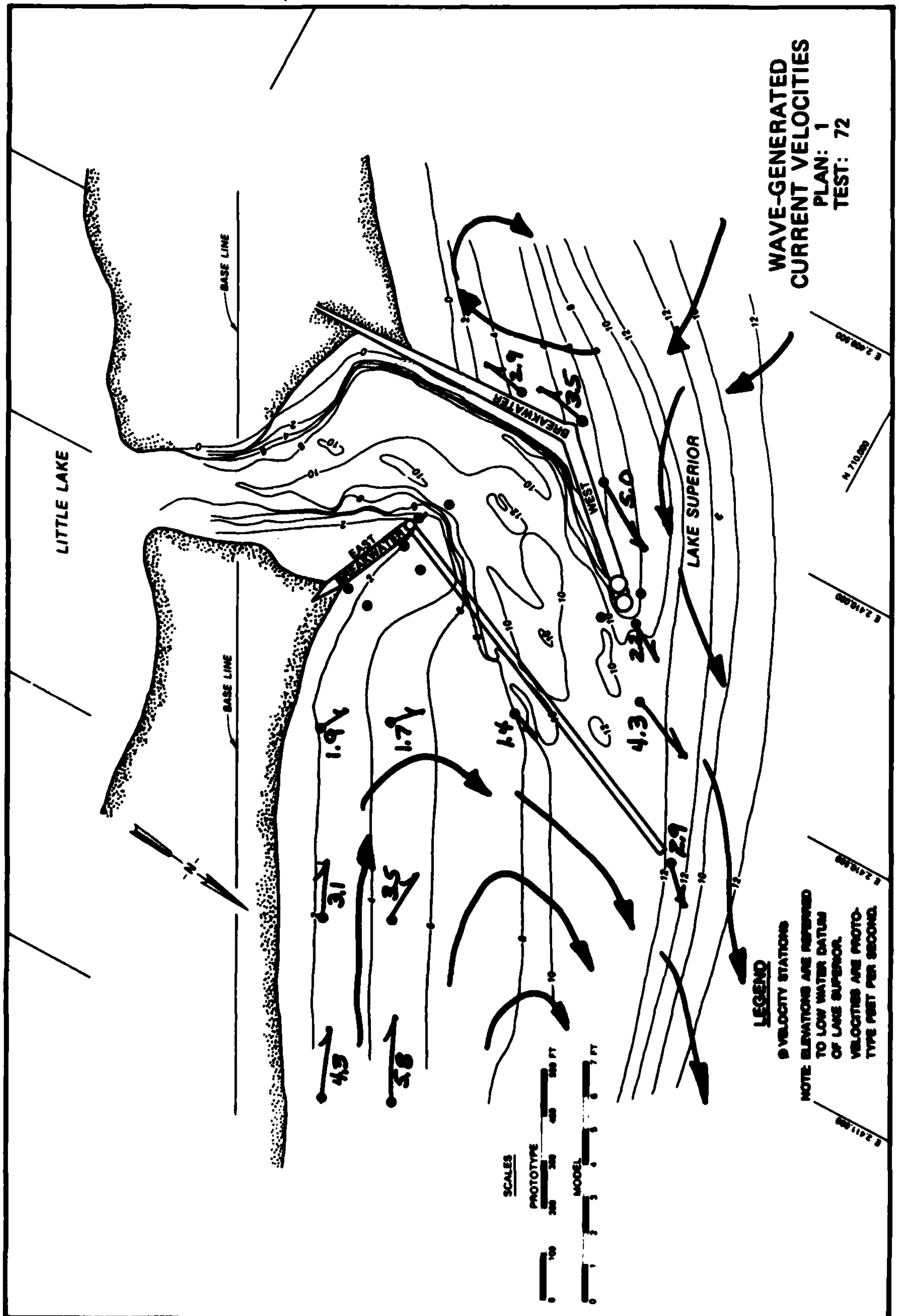

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1
TEST: 72
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
2.9
3.5
5.0
2.2
4.3
1.9
1.7
1.4
2.9
3.1
3.5
4.9
3.8

PLATE 138

CONDITION Plan 1A
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 73

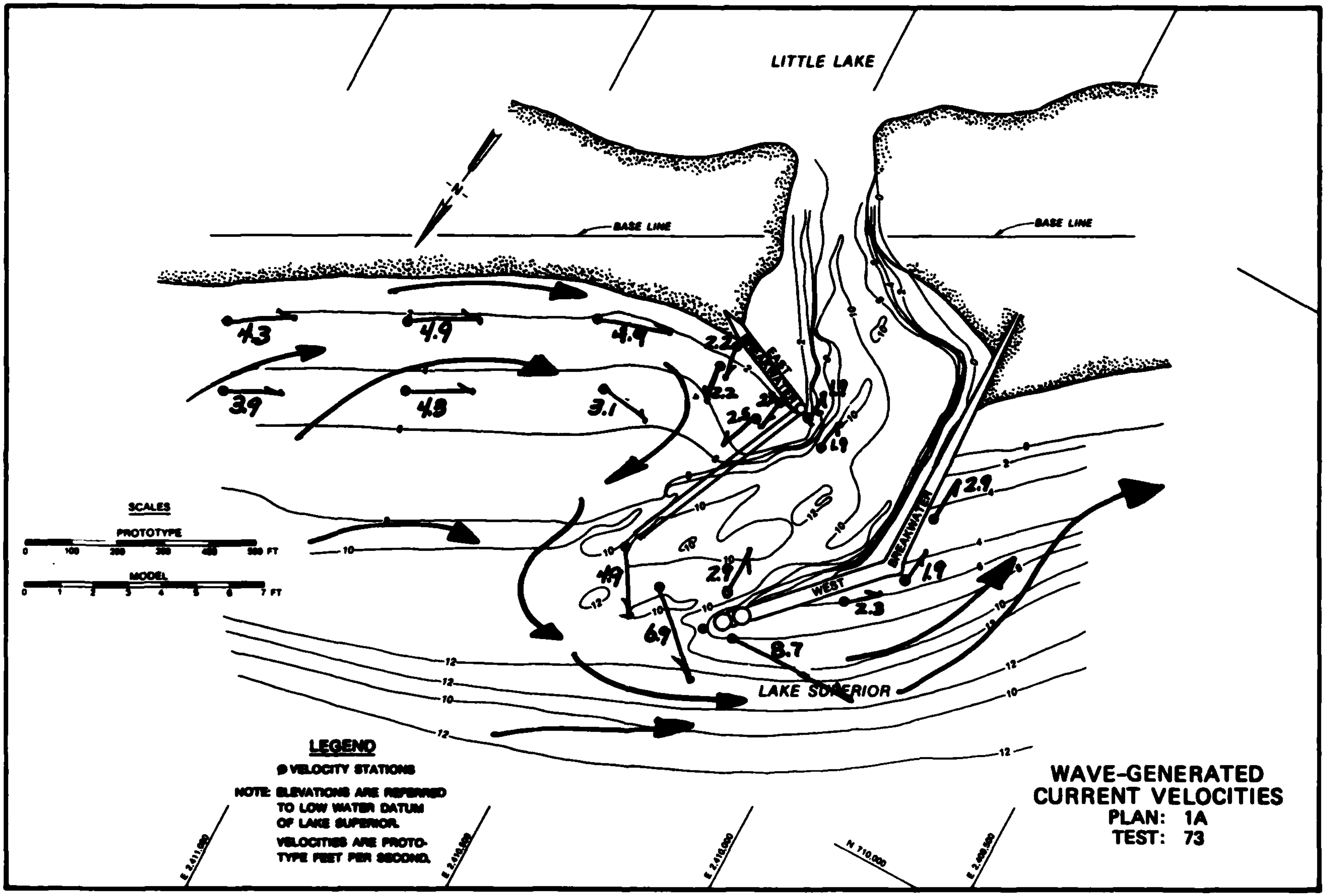
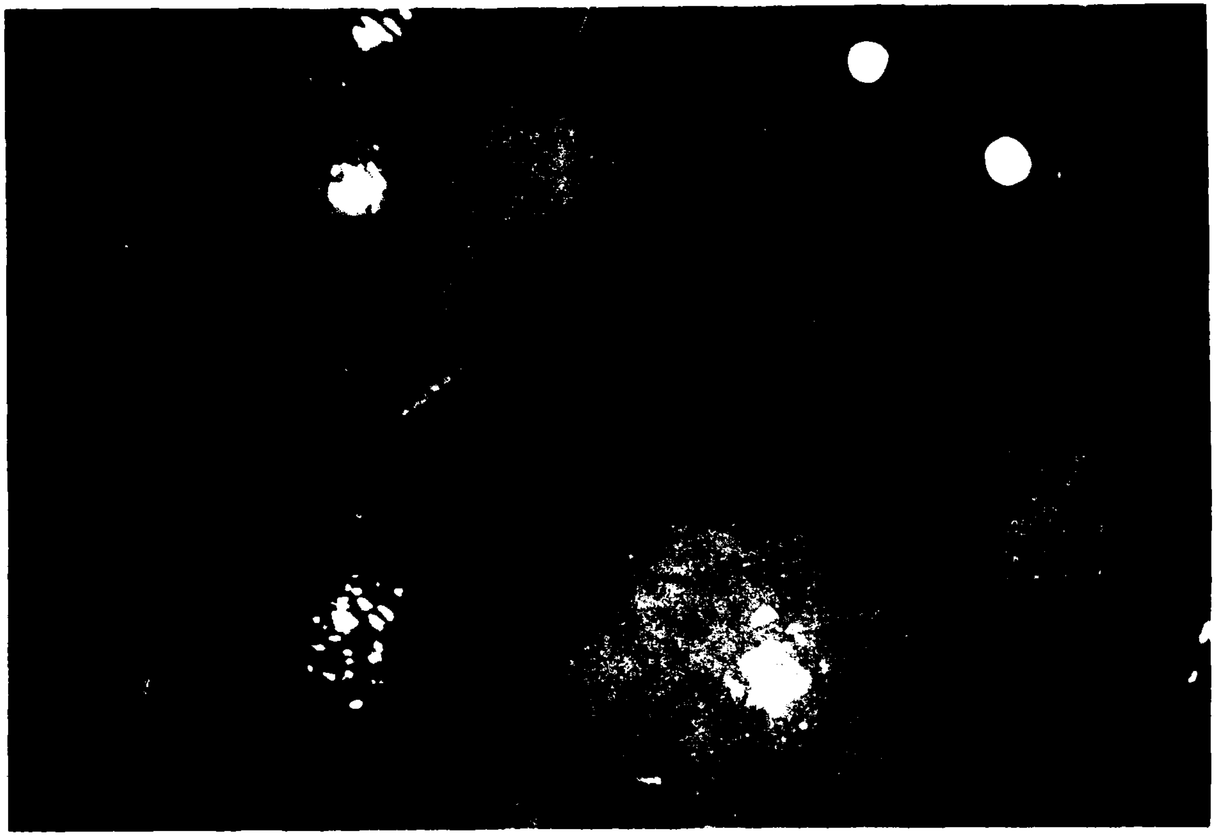
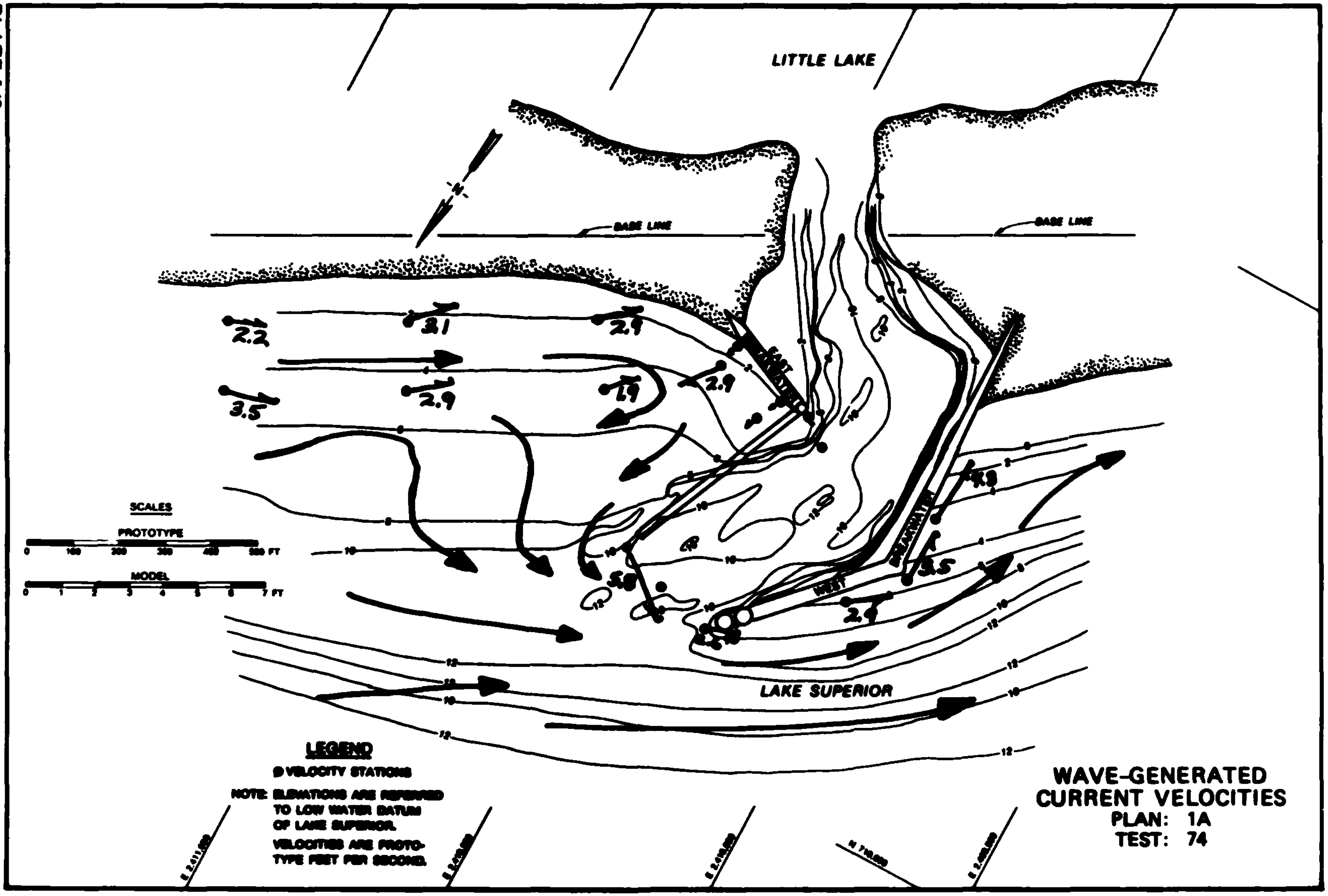

LITTLE LAKE
BASE LINE
BASE LINE
N
EAST
BREAKWATER
WEST
LAKE SUPERIOR
4.3
4.9
4.4
3.9
4.8
3.1
2.2
2.9
1.9
2.3
8.7
6.9
4.9
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1A
TEST: 73

PLATE 140



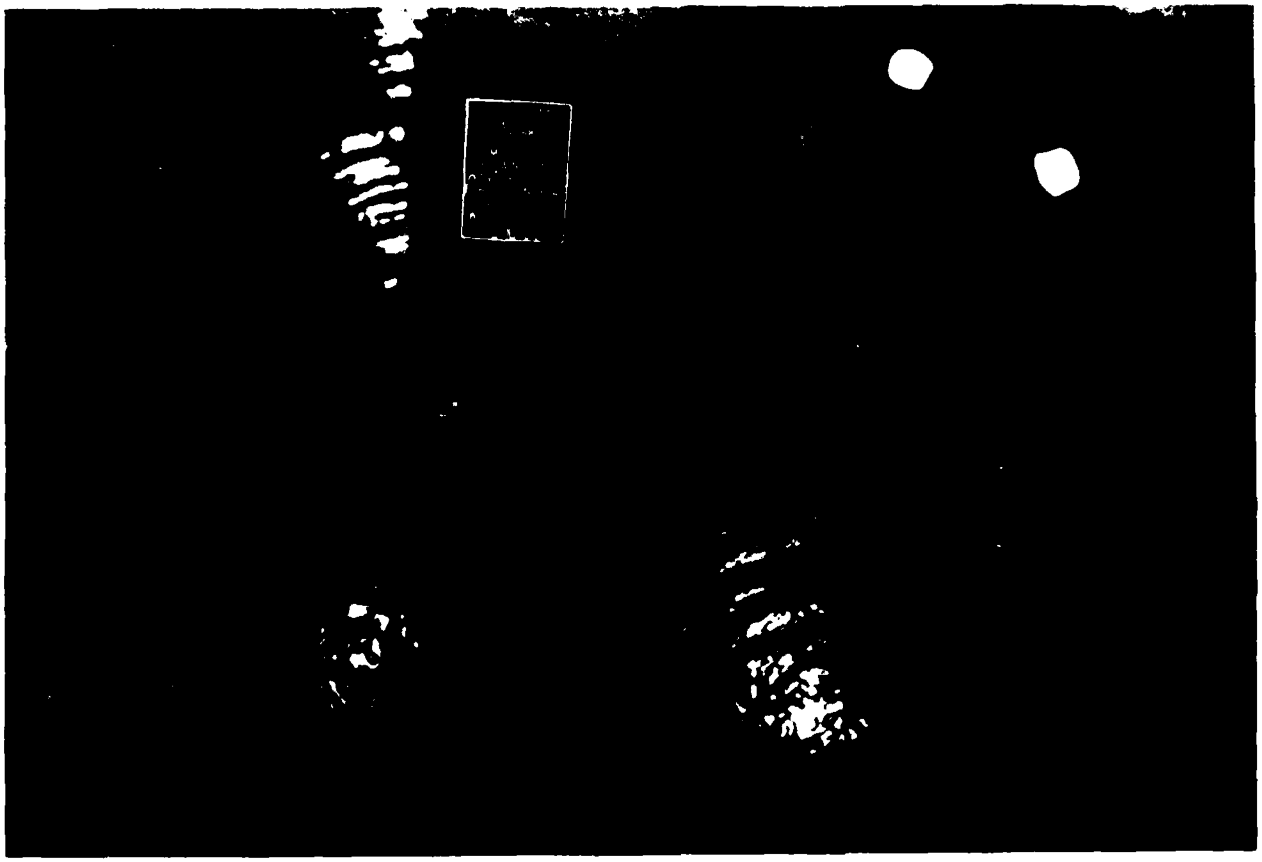
CONDITION Plan 1A
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 74



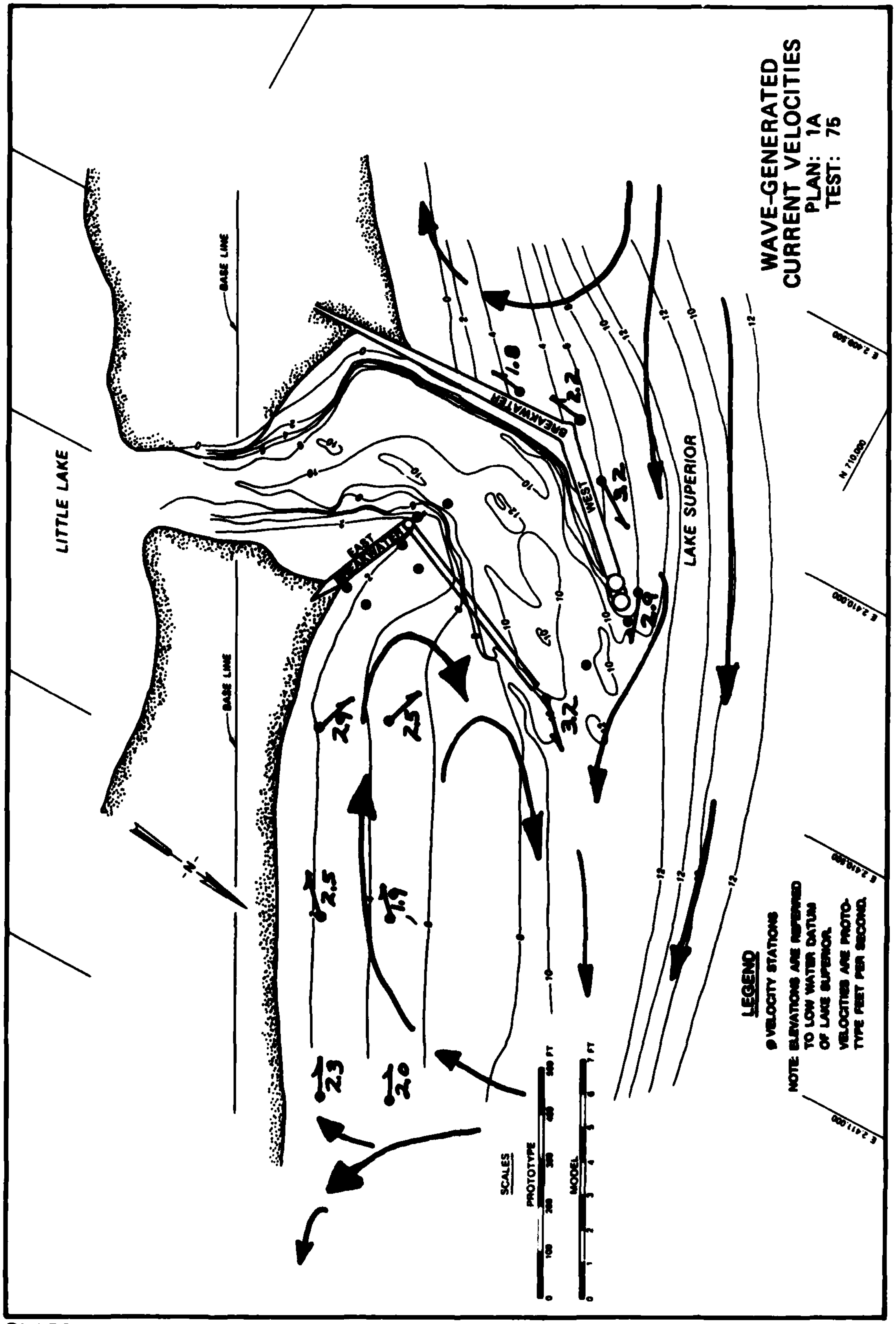
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1A
TEST: 74
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
N
2.2
3.1
2.9
3.5
2.9
1.9
2.9
5.0
2.9
3.5
4.9
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 142



CONDITION Plan 1A
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 7 5



WAVE-GENERATED CURRENT VELOCITIES
PLAN: 1A
TEST: 75

PLATE 144

CONDITION Plan 1A
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 76

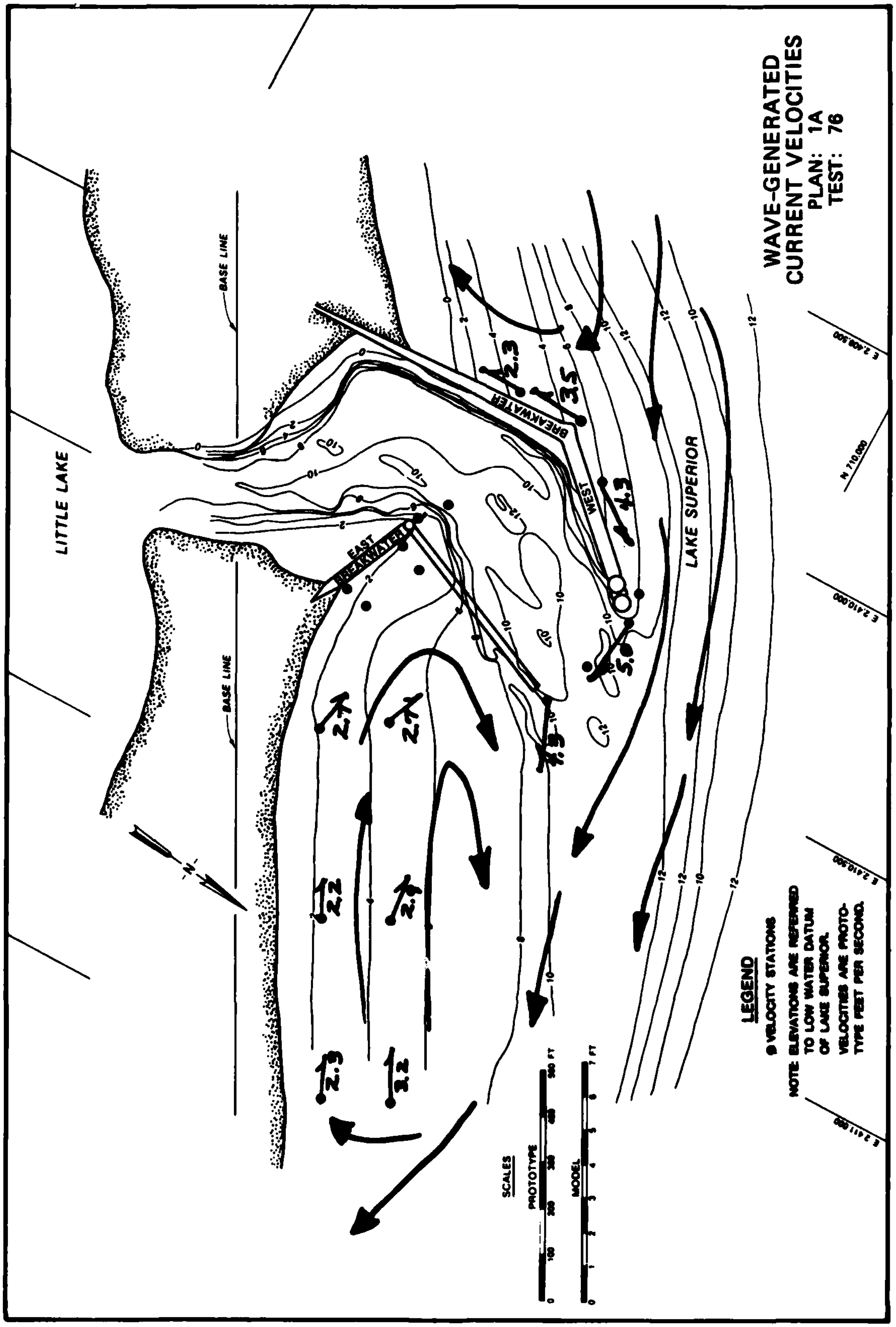
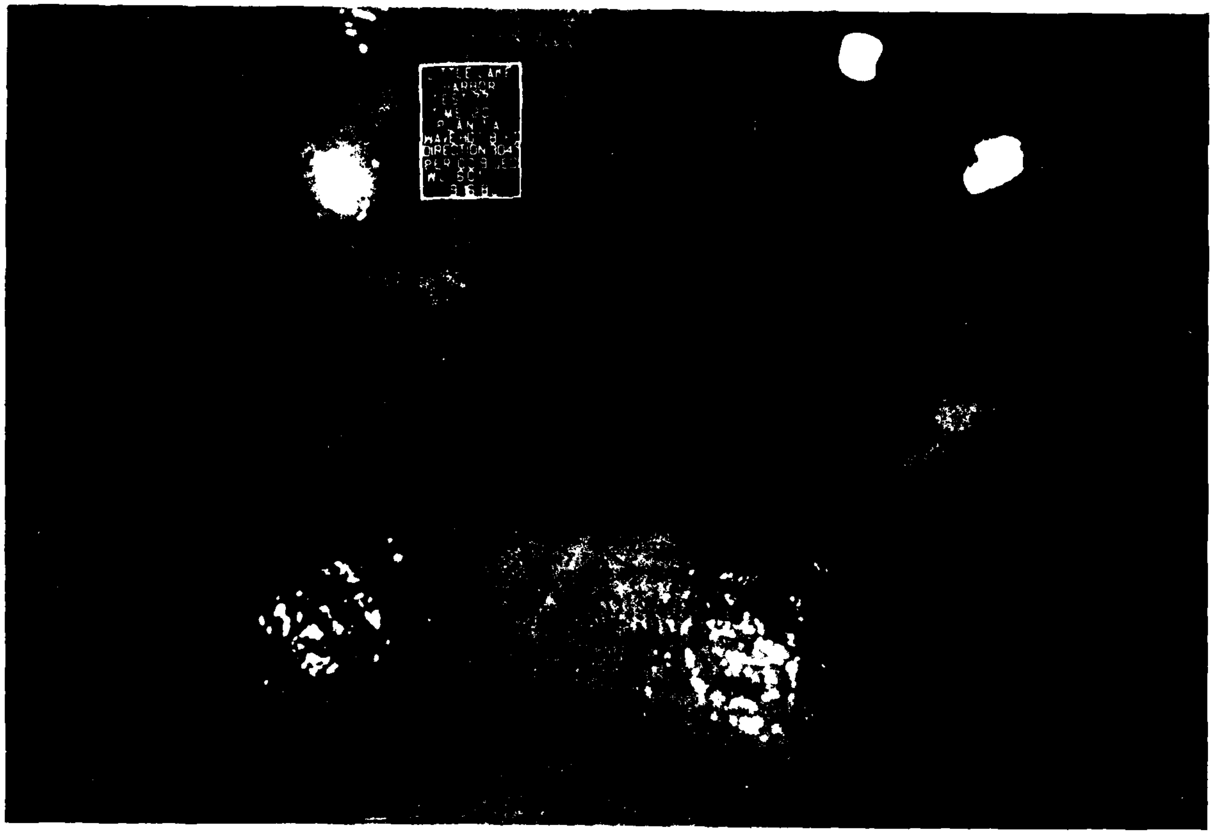
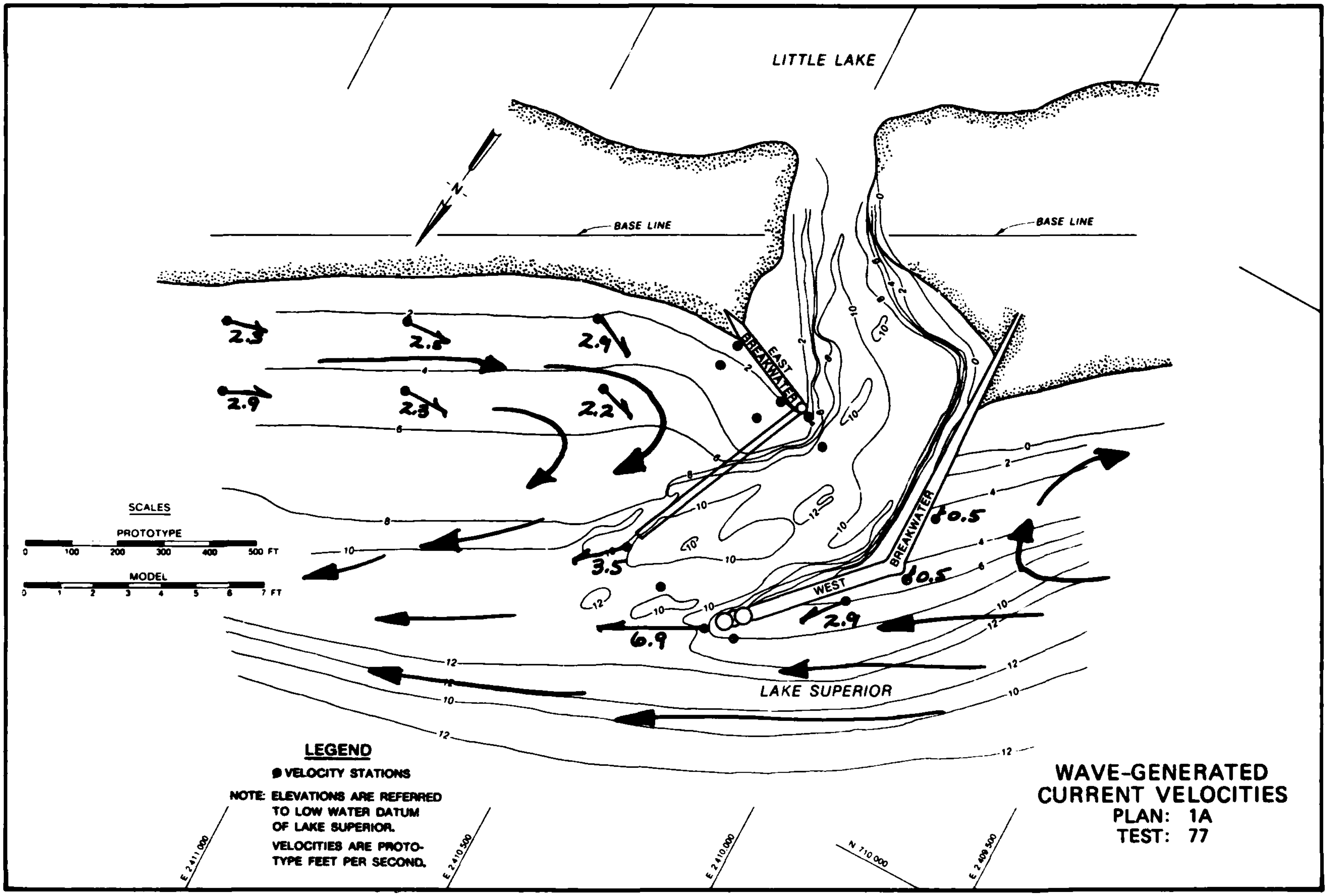

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1A
TEST: 76
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 146



CONDITION Plan 1A
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 77



LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
2.3
2.8
2.9
2.9
2.5
2.2
3.5
6.9
2.9
0.5
0.5
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 411 000
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1A
TEST: 77

PLATE 148

CONDITION Plan 1B
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 78

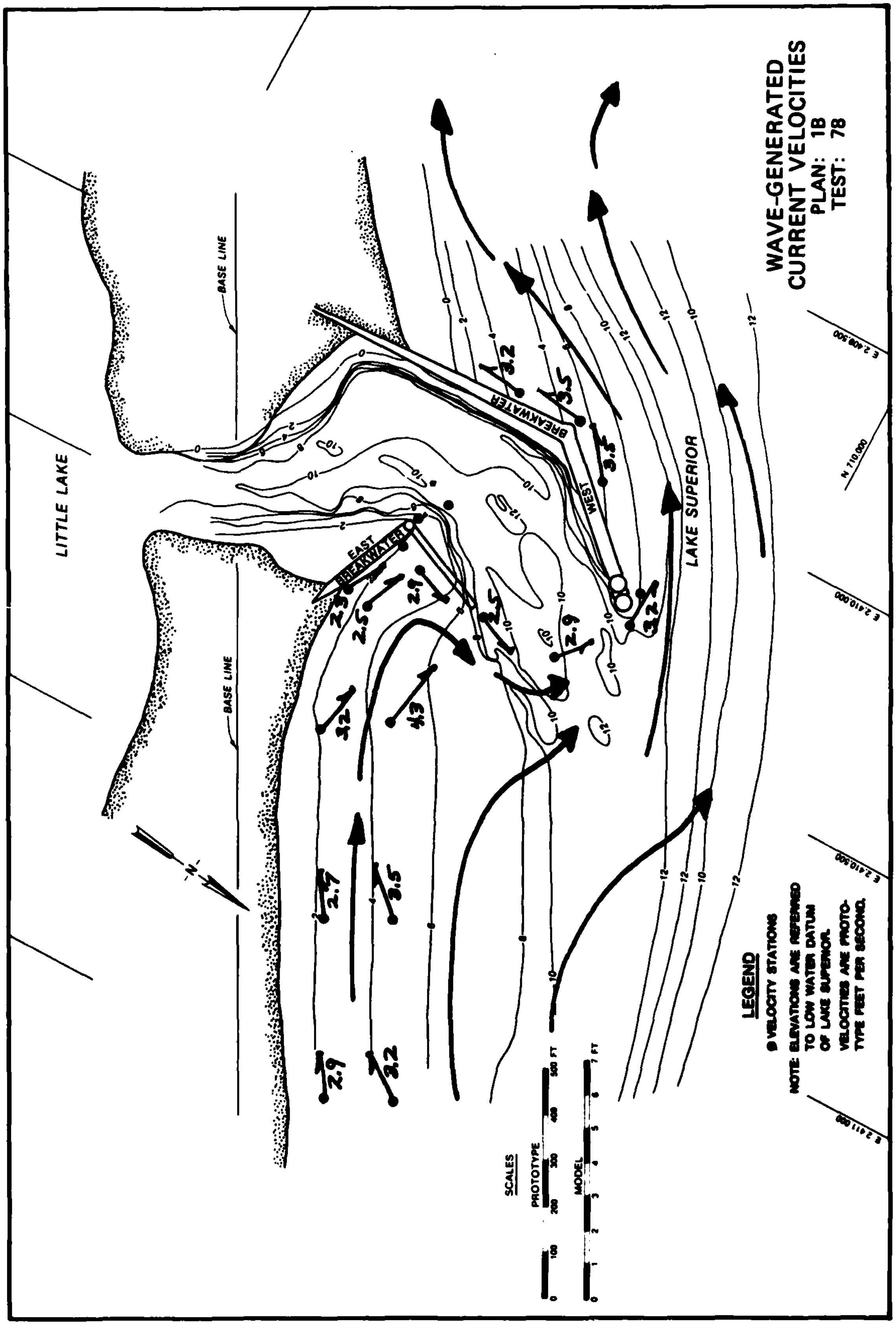

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1B
TEST: 78
LITTLE LAKE
LAKE SUPERIOR
WEST
BREAKWATER
EAST
BREAKWATER
BASE LINE
BASE LINE
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2,408,500
E 2,410,000
E 2,410,500
E 2,411,000
N 710,000

PLATE 150

CONDITION Plan 1B
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 79

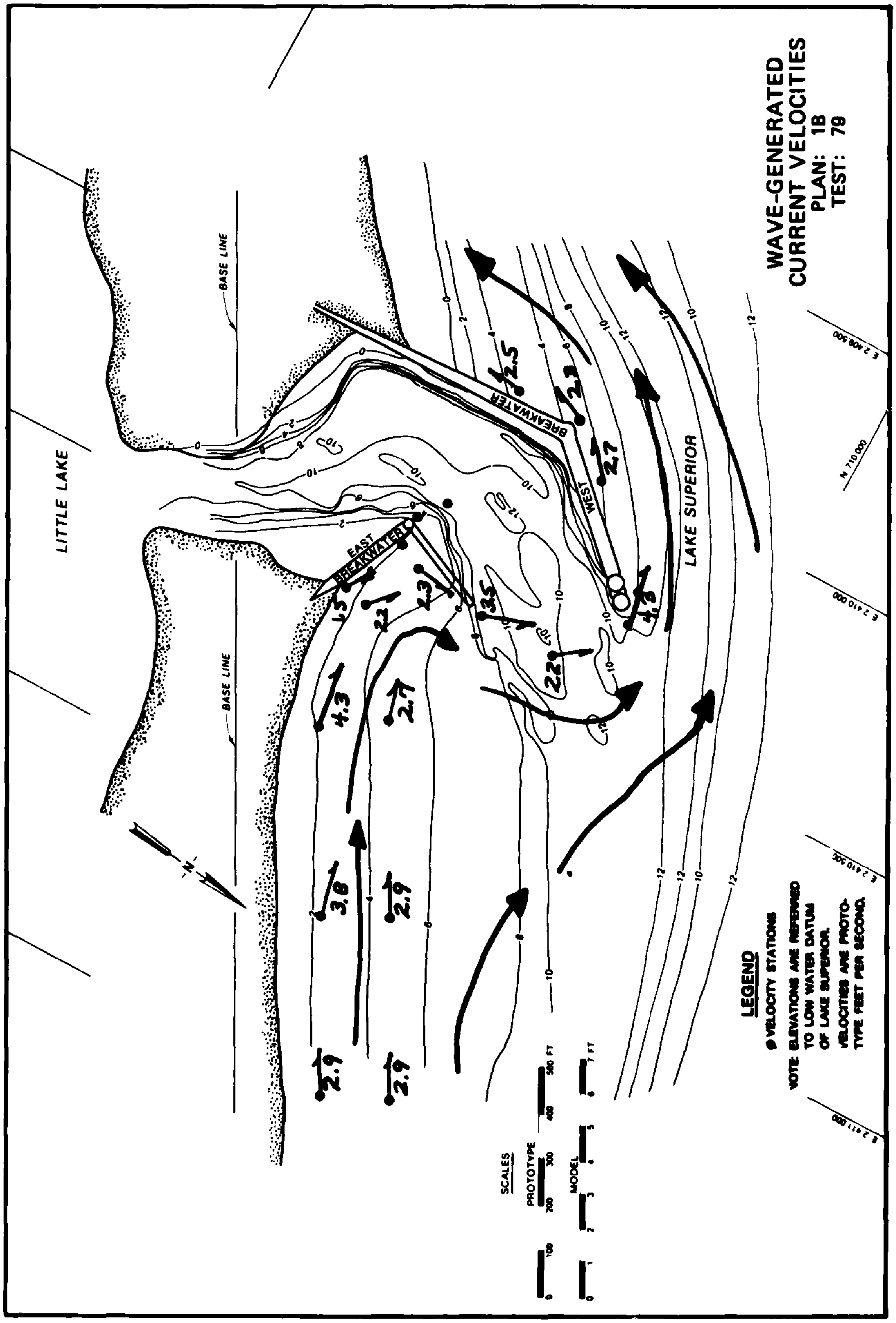
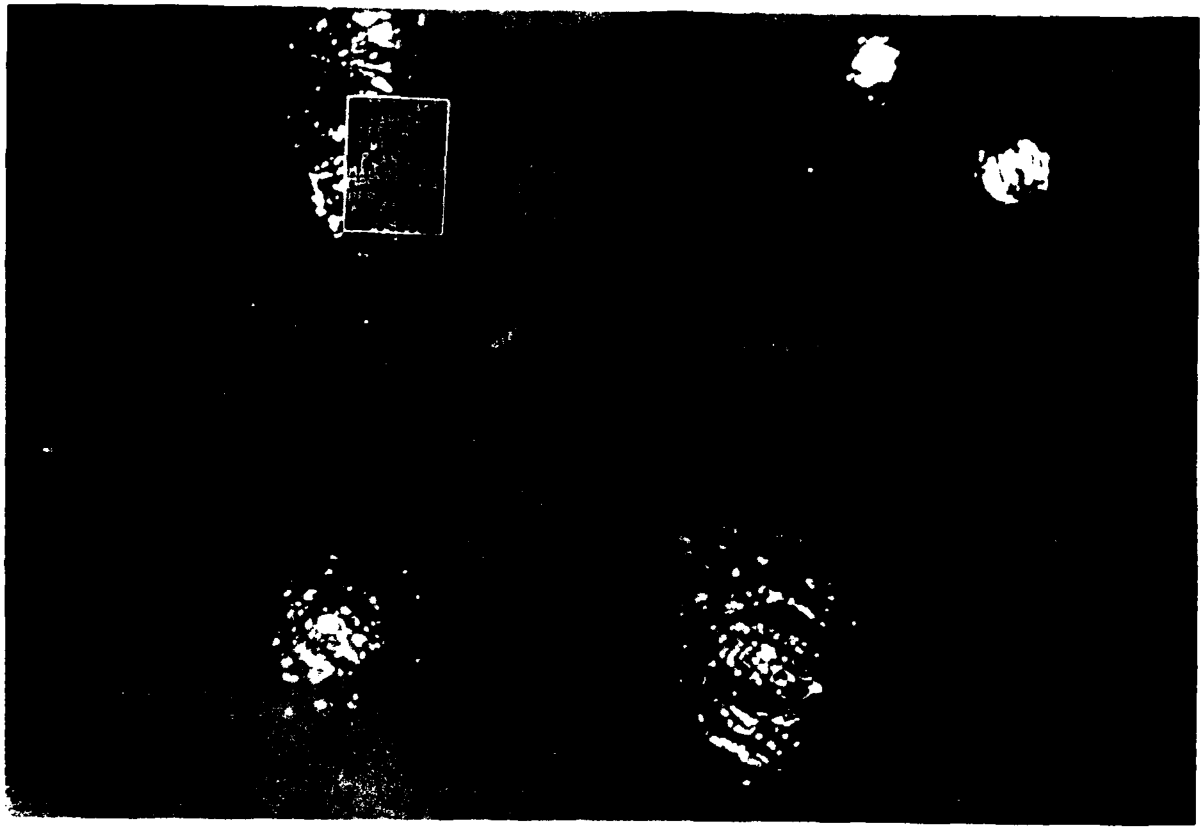
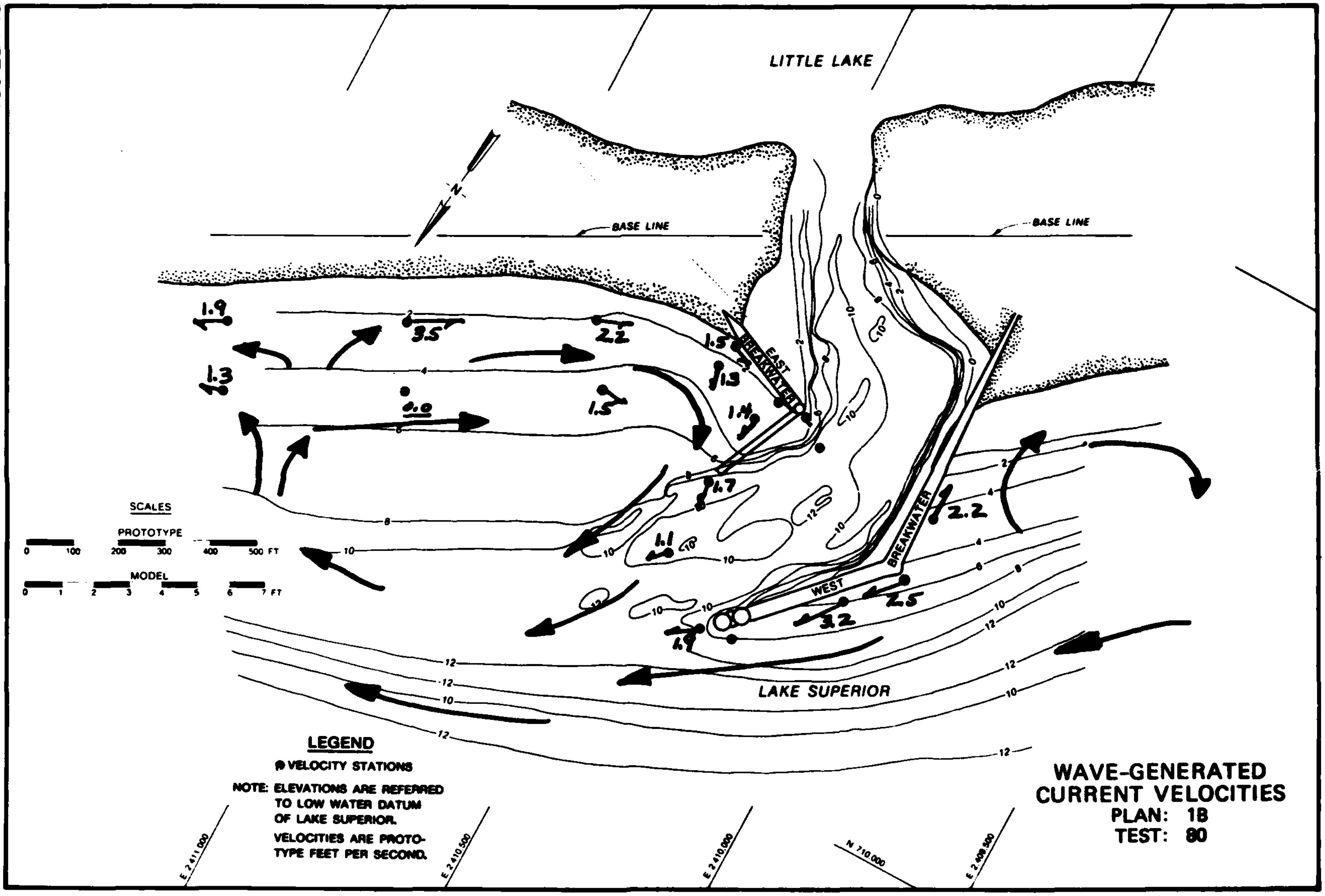

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1B
TEST: 79
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
N 710 000

PLATE 152



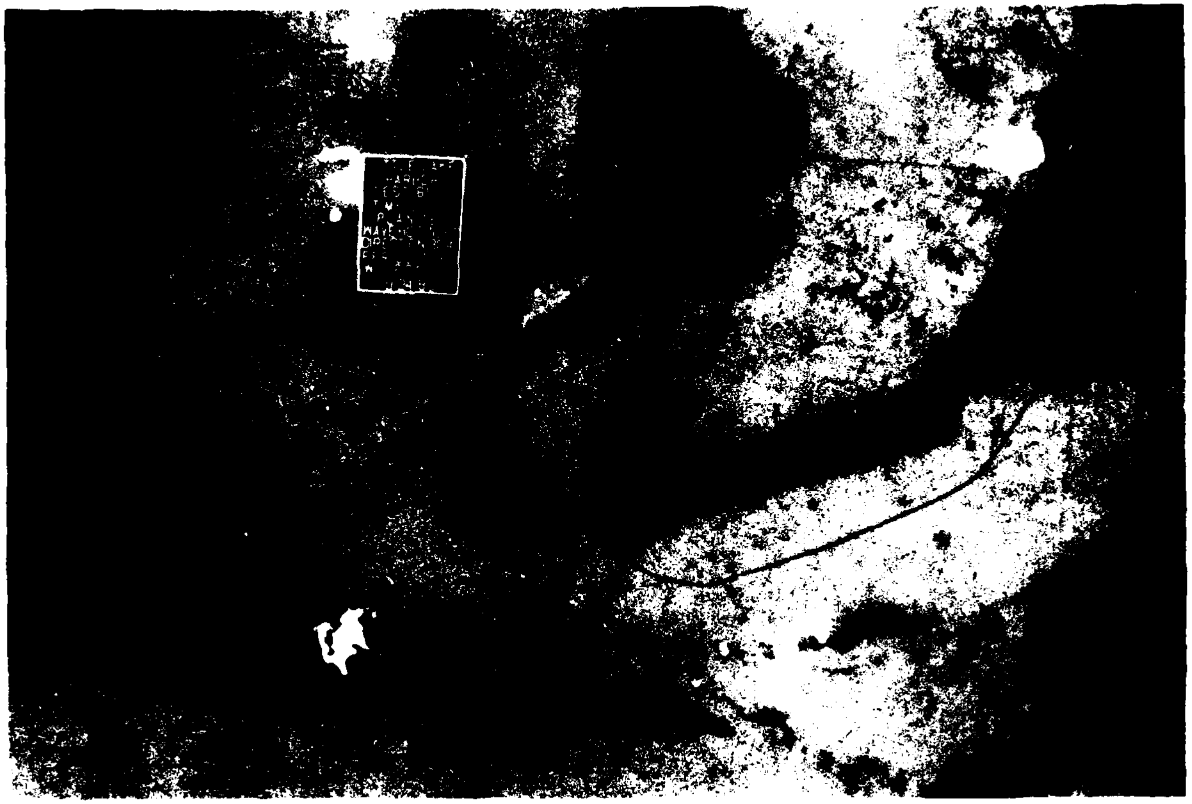
CONDITION Plan 1B
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 80



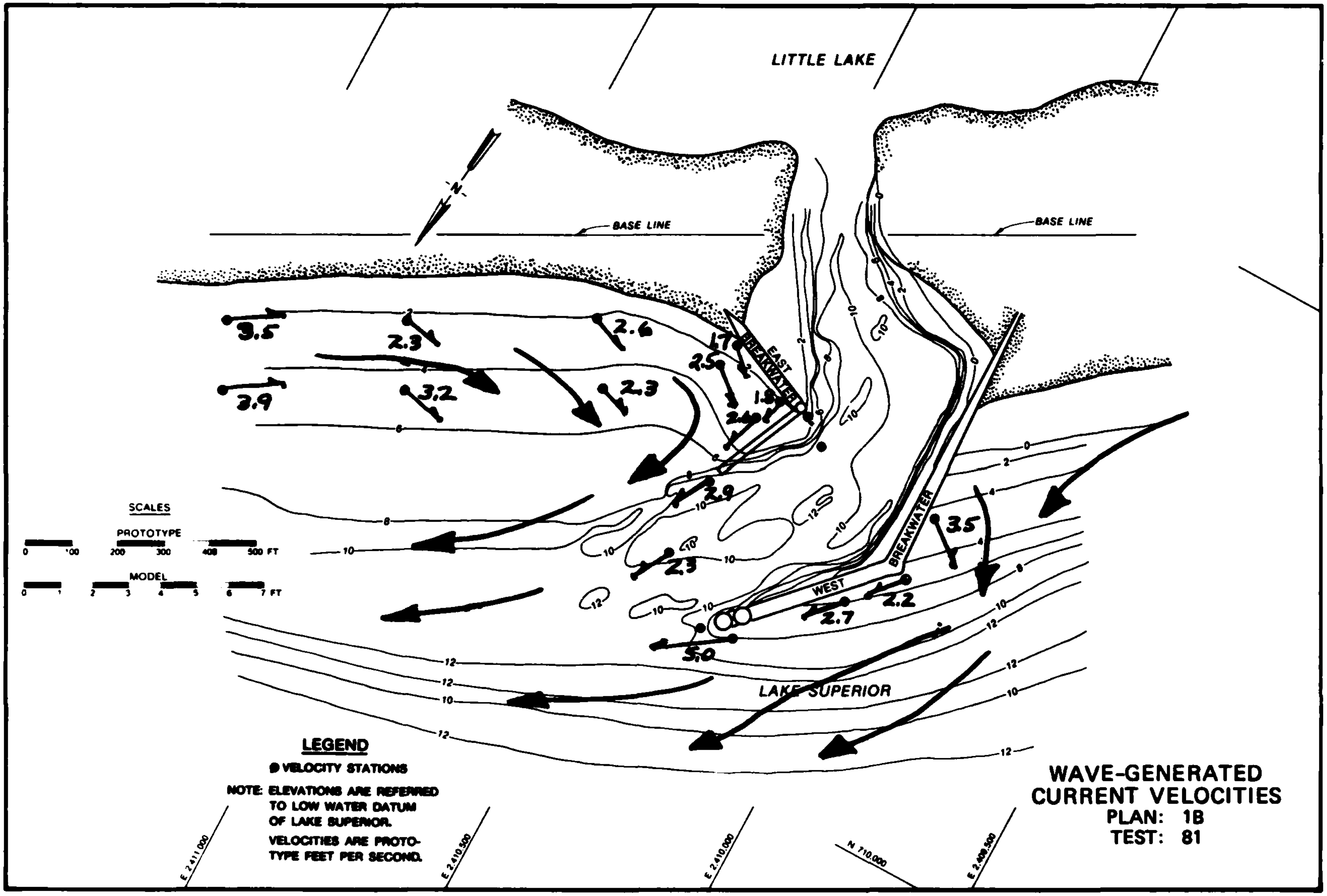
LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
1.9
3.5
2.2
1.3
2.0
1.5
1.5
1.3
1.4
1.7
1.1
2.2
2.5
3.2
1.9
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 411 000
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1B
TEST: 80

PLATE 154

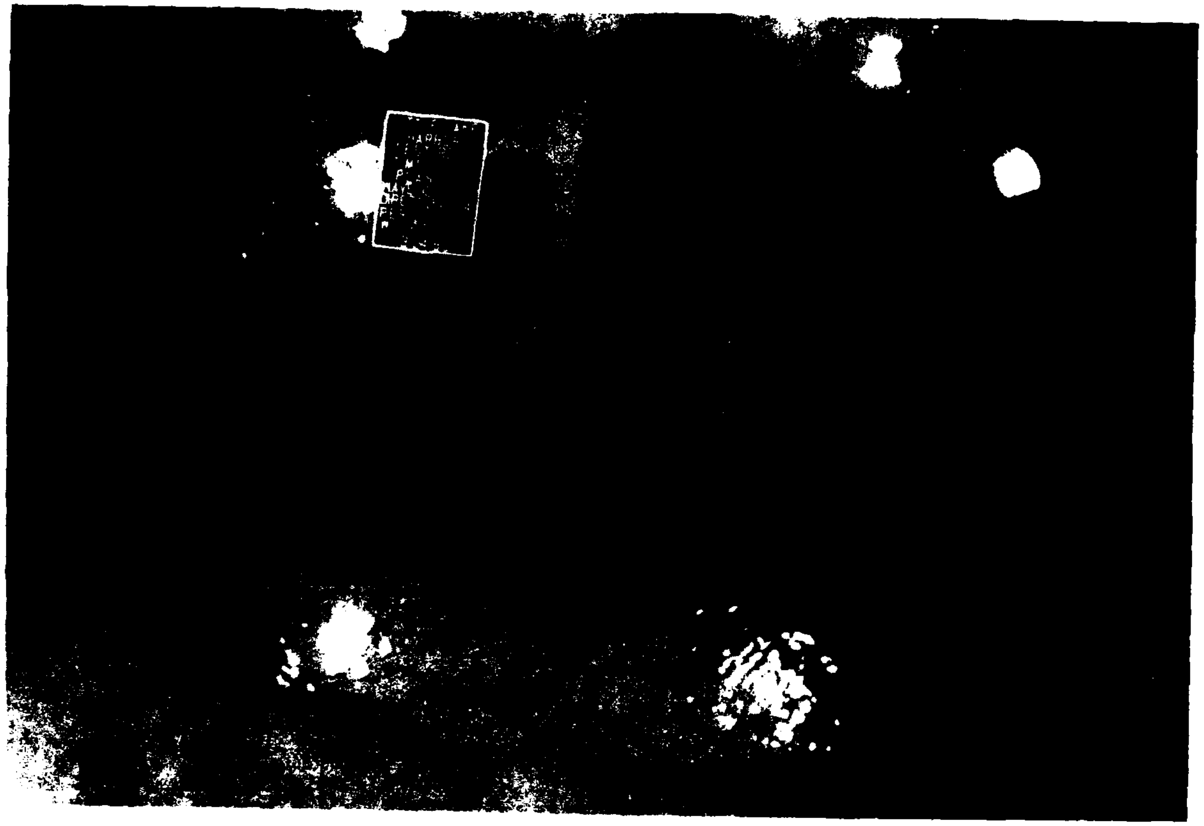


CONDITION Plan 1B
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 81

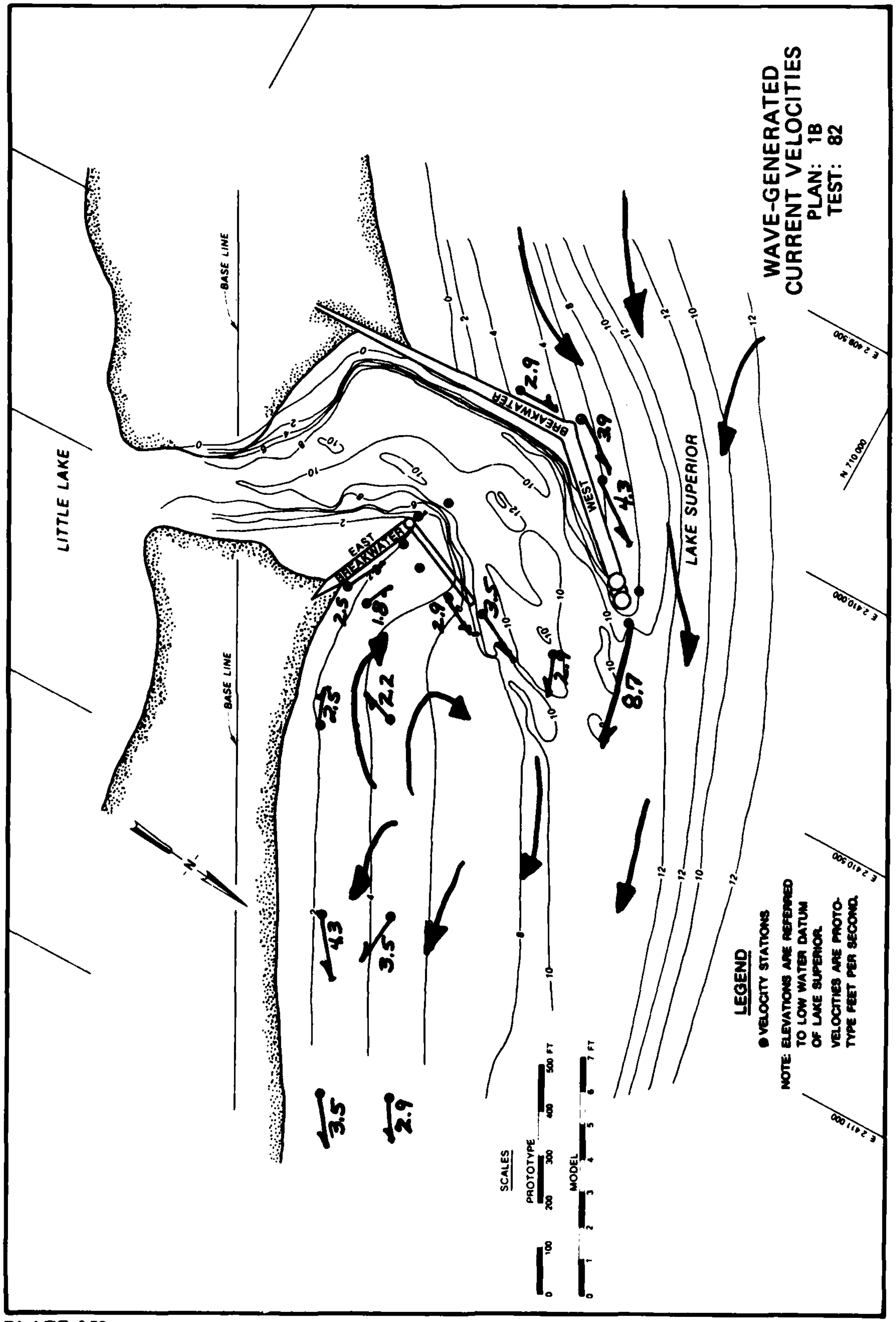


LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
3.5
2.3
2.6
3.9
3.2
2.3
1.7
2.5
1.8
2.4
2.9
2.3
3.5
2.2
2.7
5.0
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1B
TEST: 81



CONDITION Plan 1B
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 82

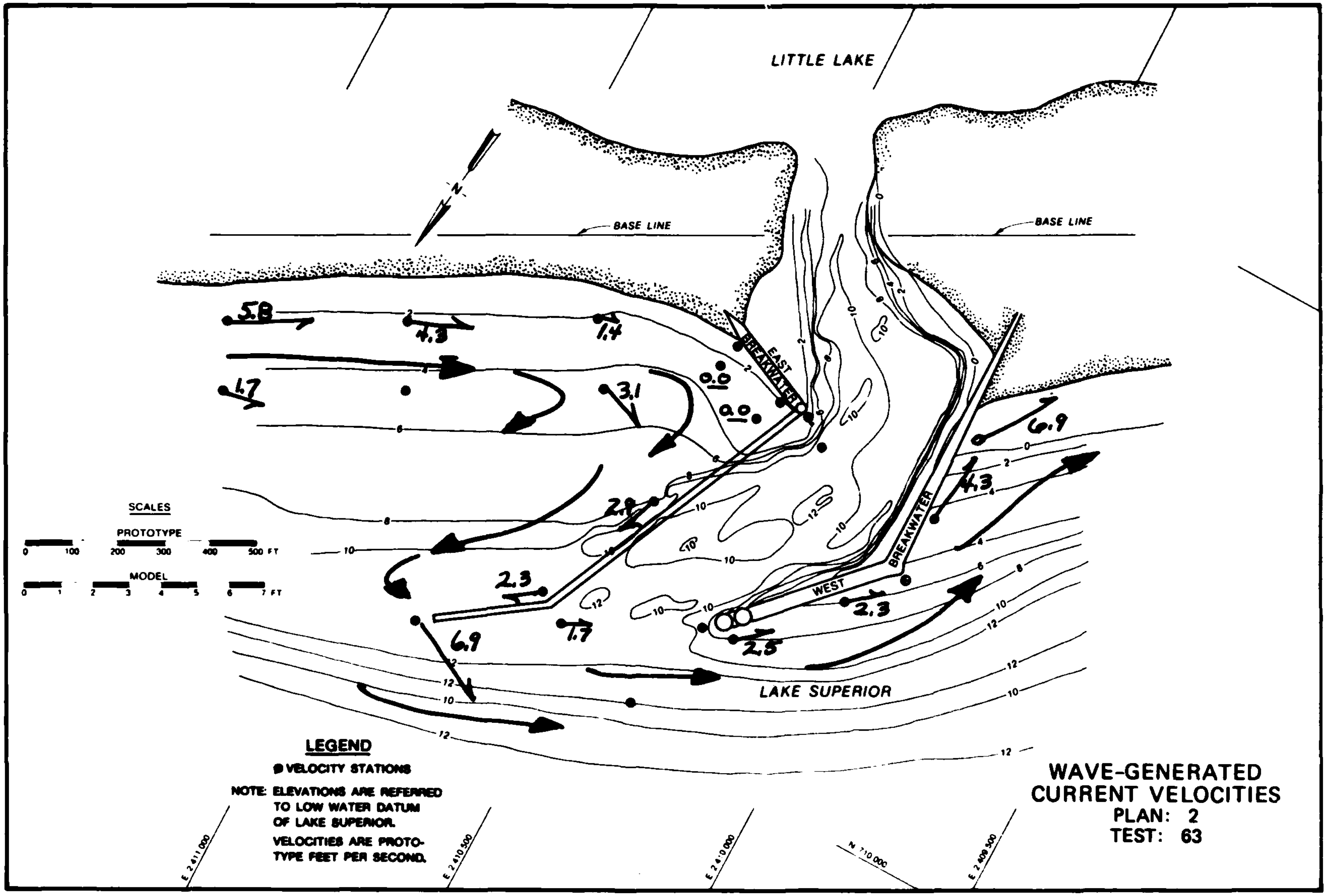


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 1B
TEST: 82
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
E 2 408 500
N 710 000
E 2 410 000
E 2 410 500
E 2 411 000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 158

CONDITION Plan 2
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 63



WAVE-GENERATED CURRENT VELOCITIES
PLAN: 2
TEST: 63

PLATE 160

CONDITION Plan 2
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 64

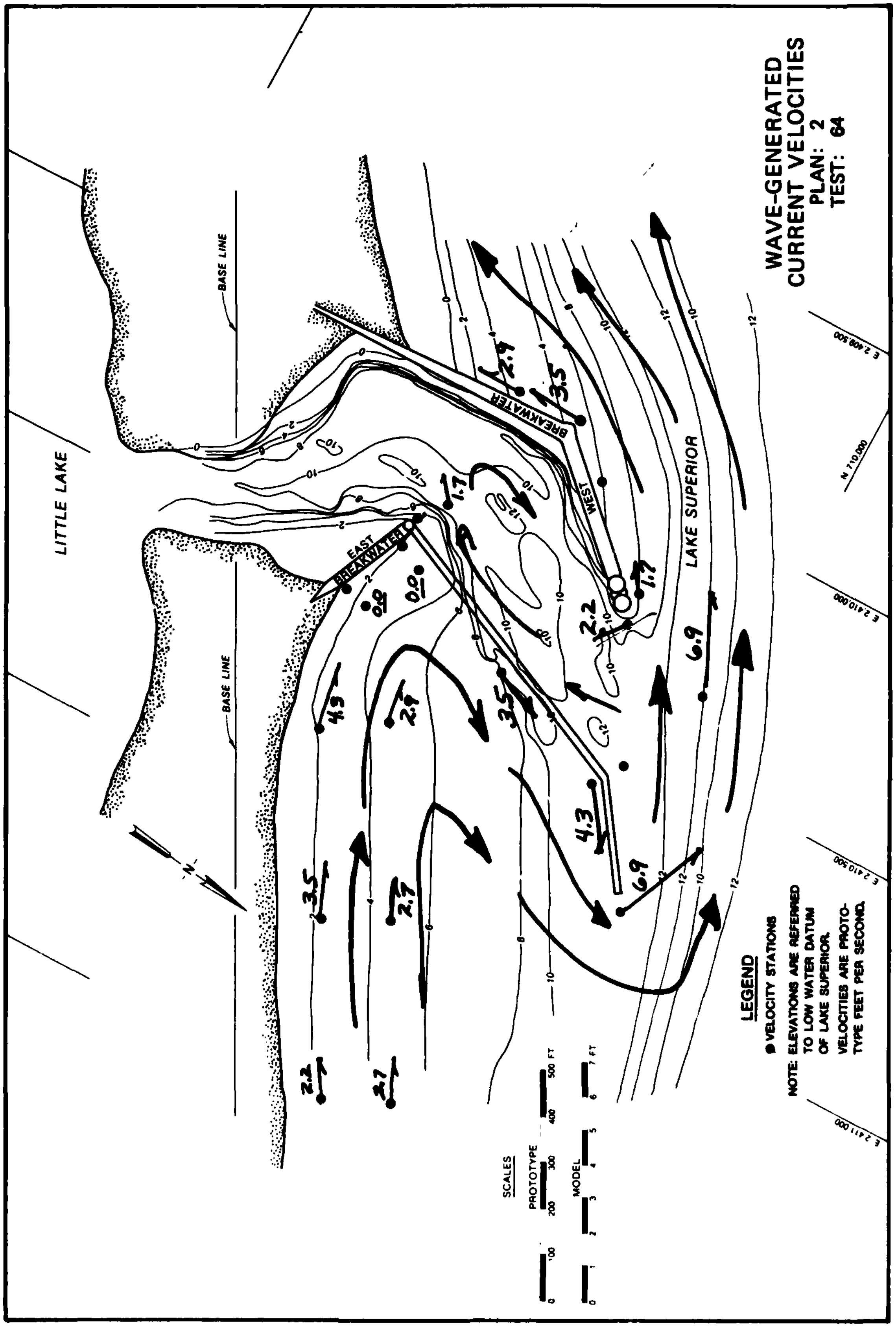

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 2
TEST: 64
LITTLE LAKE
LAKE SUPERIOR
WEST
BREAKWATER
EAST
BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
N 710,000
E 2,409,500
E 2,410,000
E 2,410,500
E 2,411,000

PLATE 162

CONDITION Plan 2
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 65

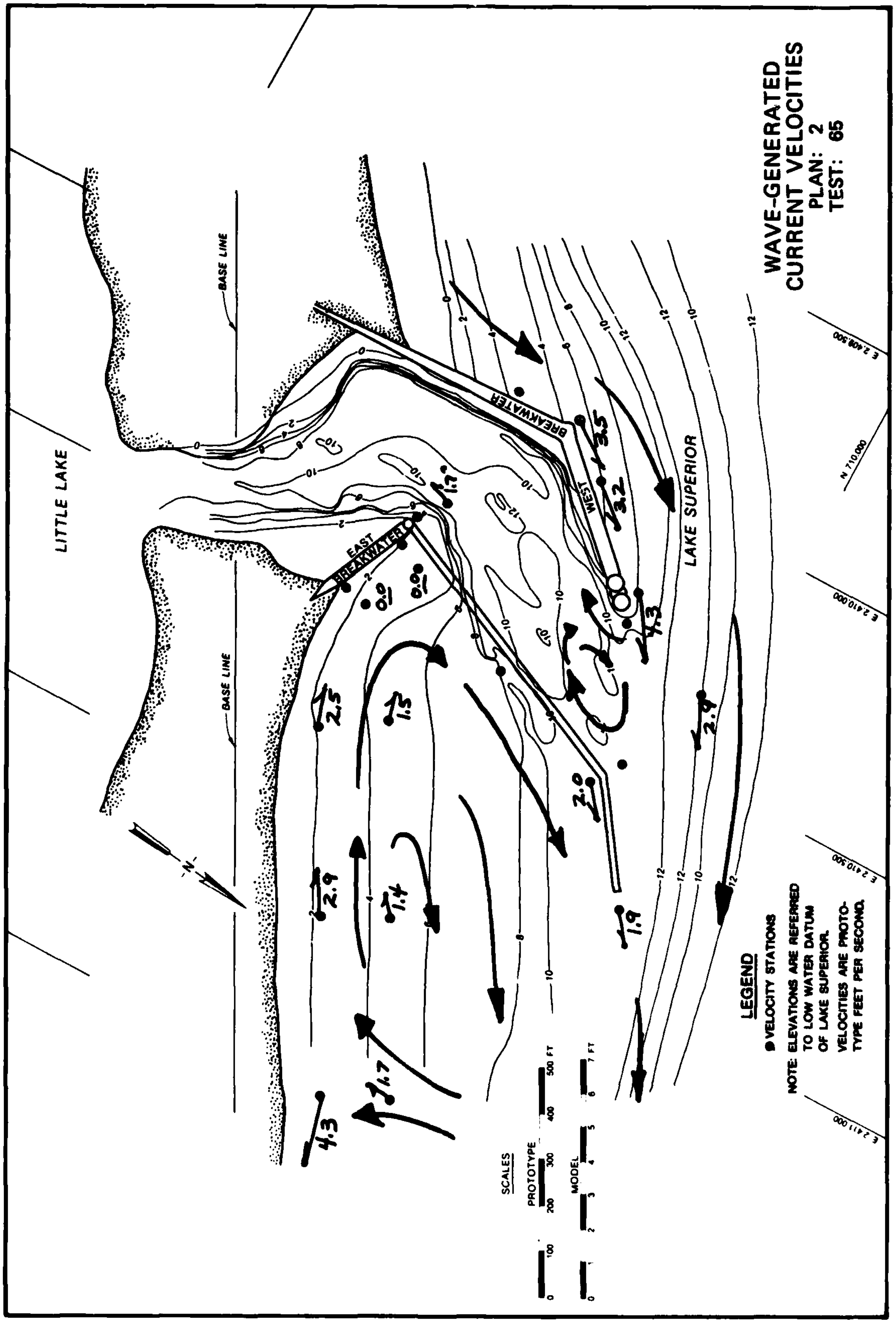
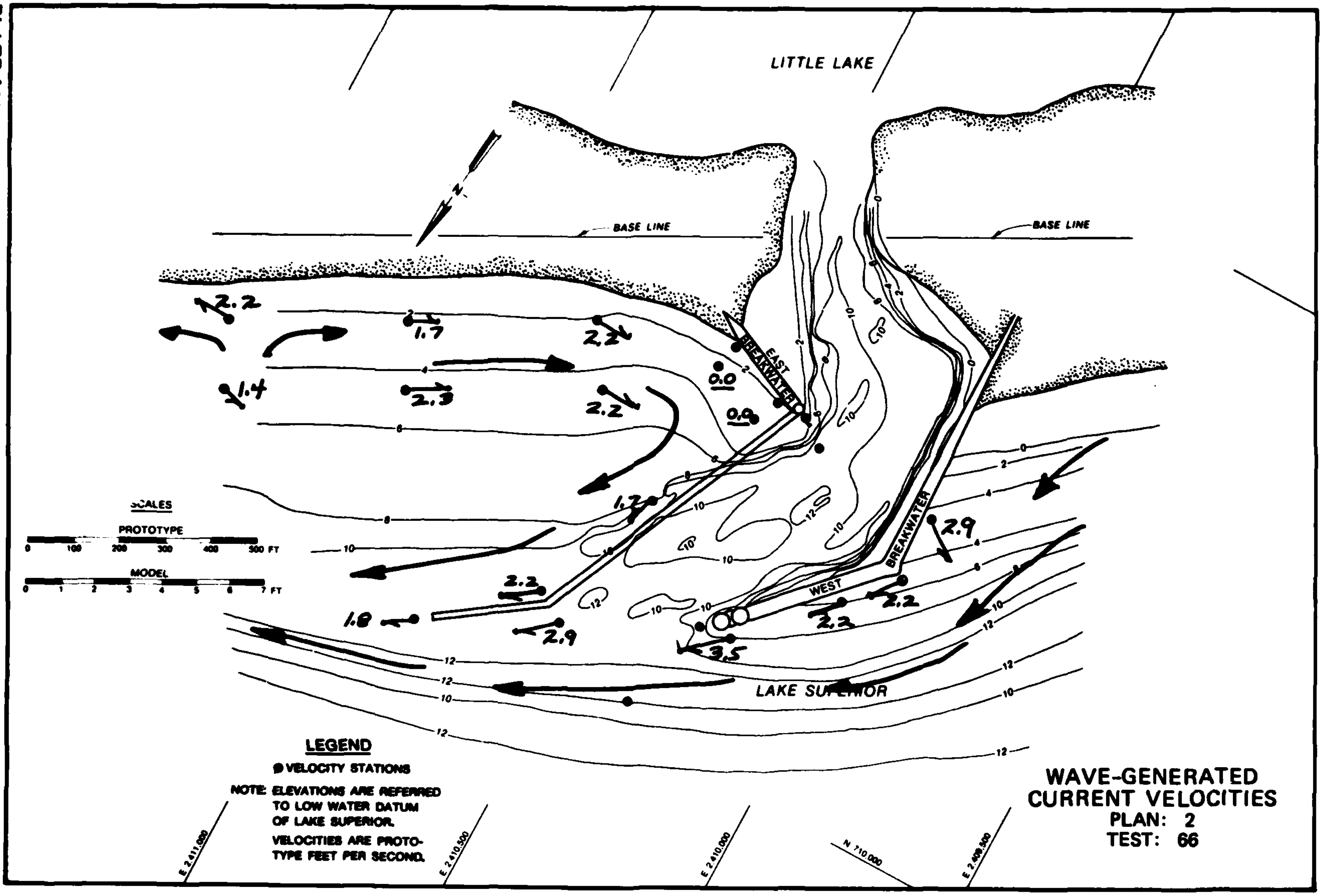

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 2
TEST: 65
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
E 2,408,500
N 710,000
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
3.5
3.2
1.7
0.0
0.0
4.3
2.5
1.5
2.0
2.9
2.9
1.4
1.9
1.7
4.3

PLATE 164

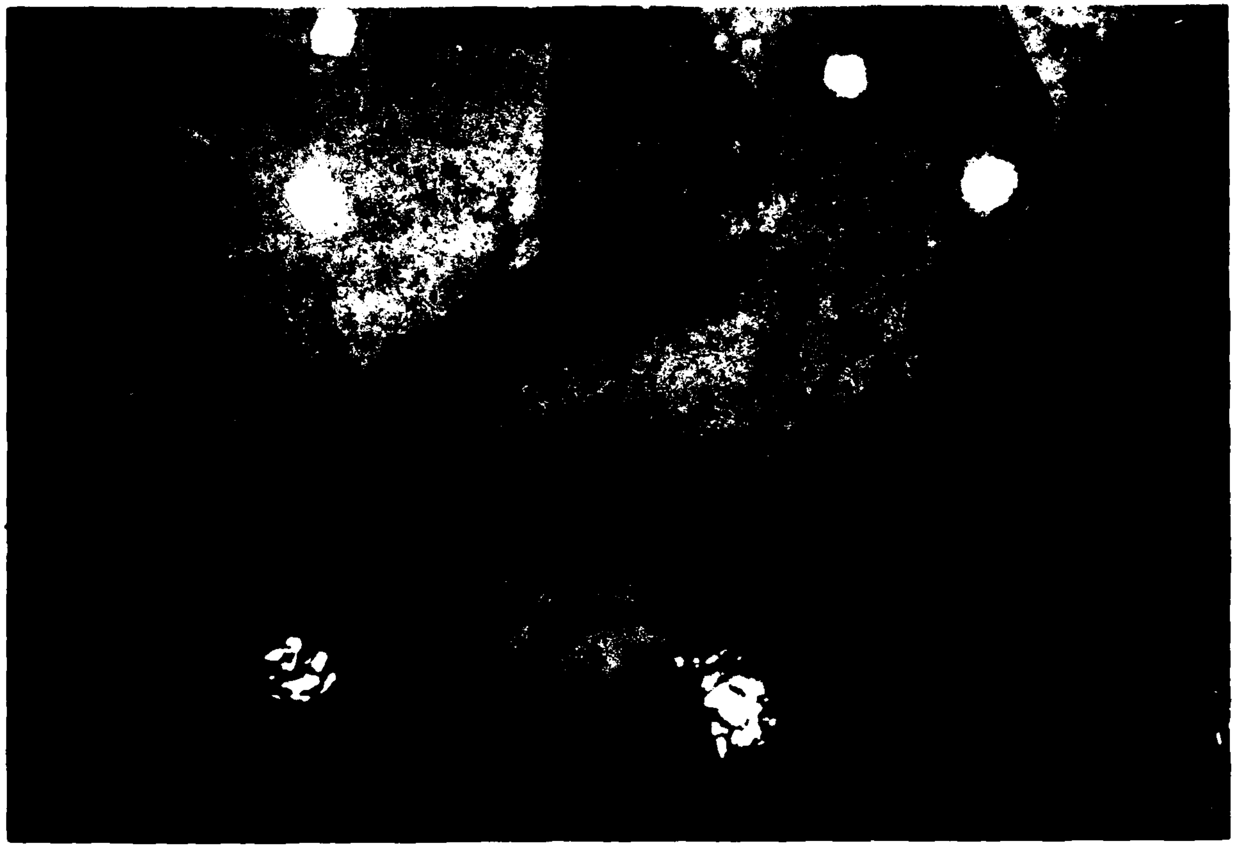
CONDITION Plan 2
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 66



LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 2
TEST: 66

PLATE 166



CONDITION Plan 2
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 67

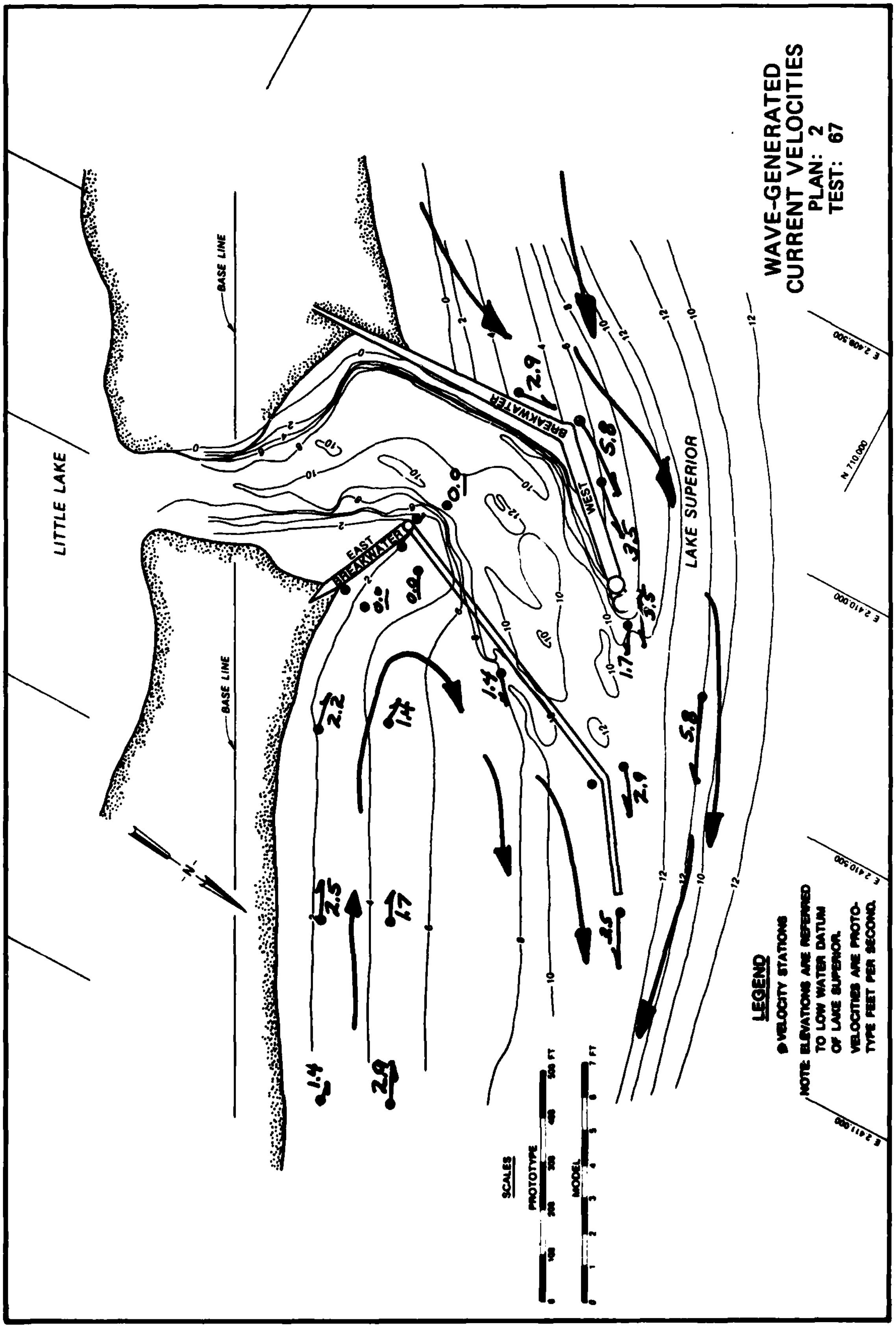

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 2
TEST: 67
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
WEST
BREAKWATER
EAST
BREAKWATER
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL
N 710,000
E 2,408,500
E 2,410,000
E 2,410,500
E 2,411,000

PLATE 168

CONDITION Plan 3
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 58

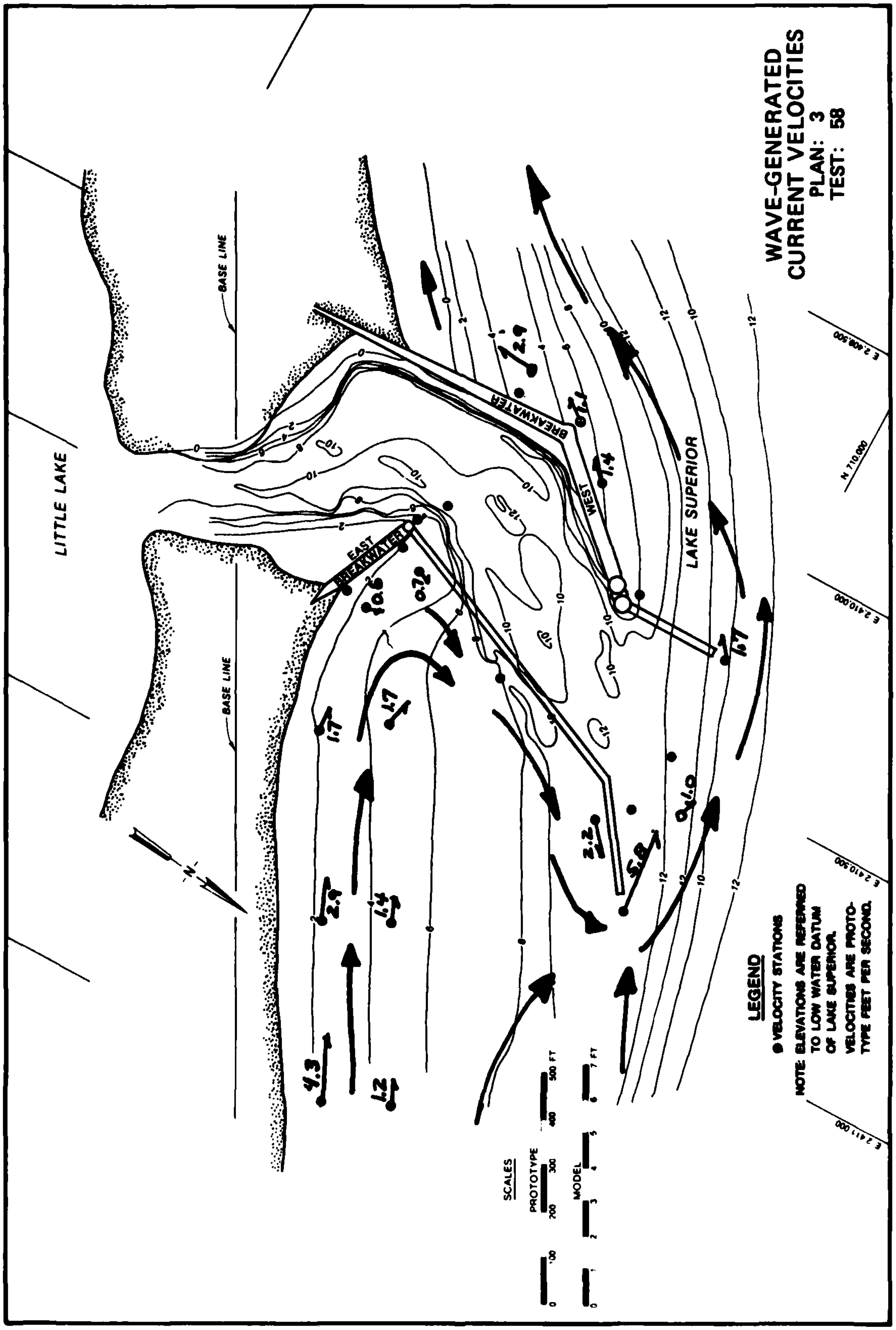
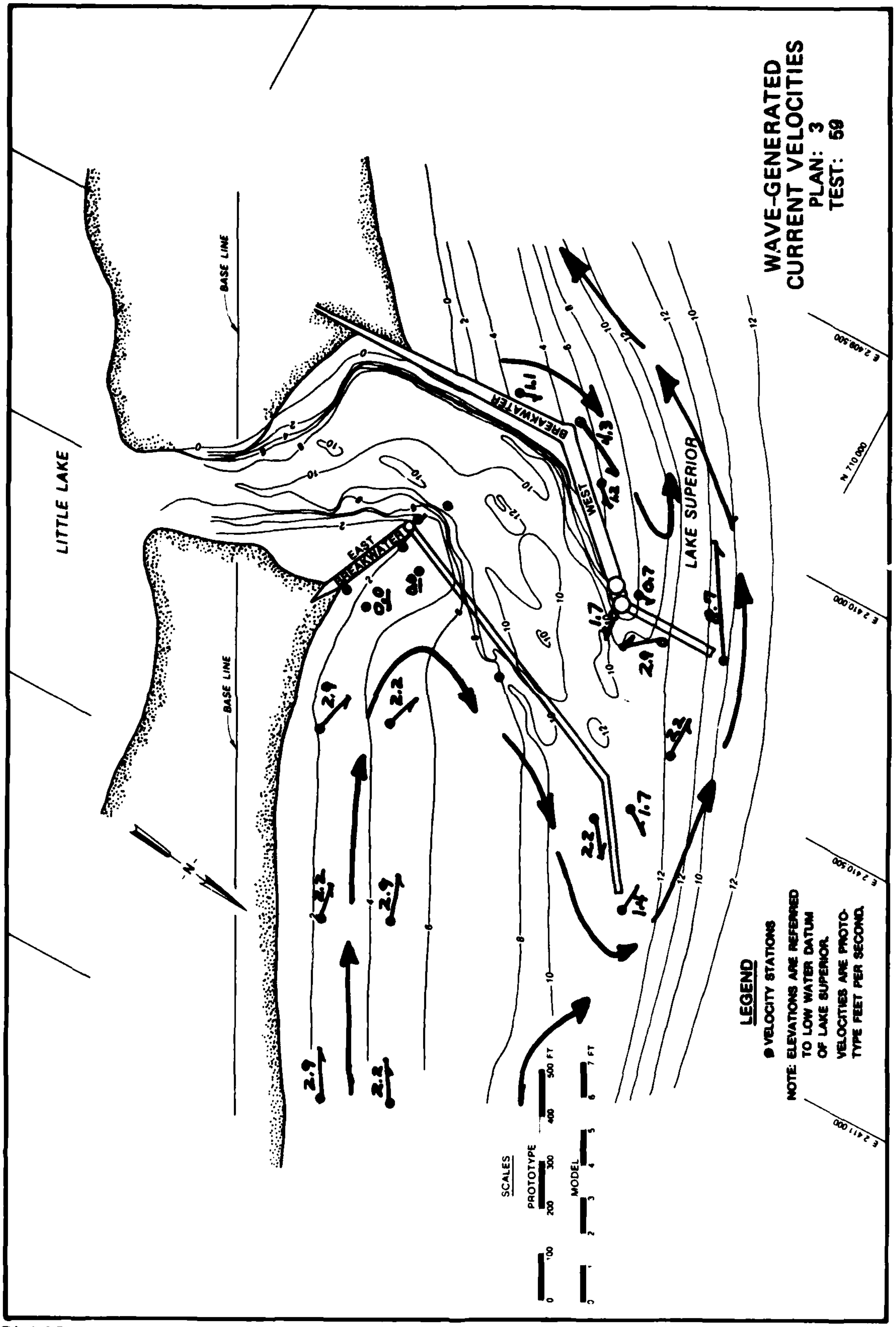

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 3
TEST: 58
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N 710,000
E 2,408,500
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 170

CONDITION Plan 3
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 59



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 3
TEST: 59
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N 710 000
E 2 408 500
E 2 410 000
E 2 410 500
E 2 411 000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 172

CONDITION Plan 3
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 60

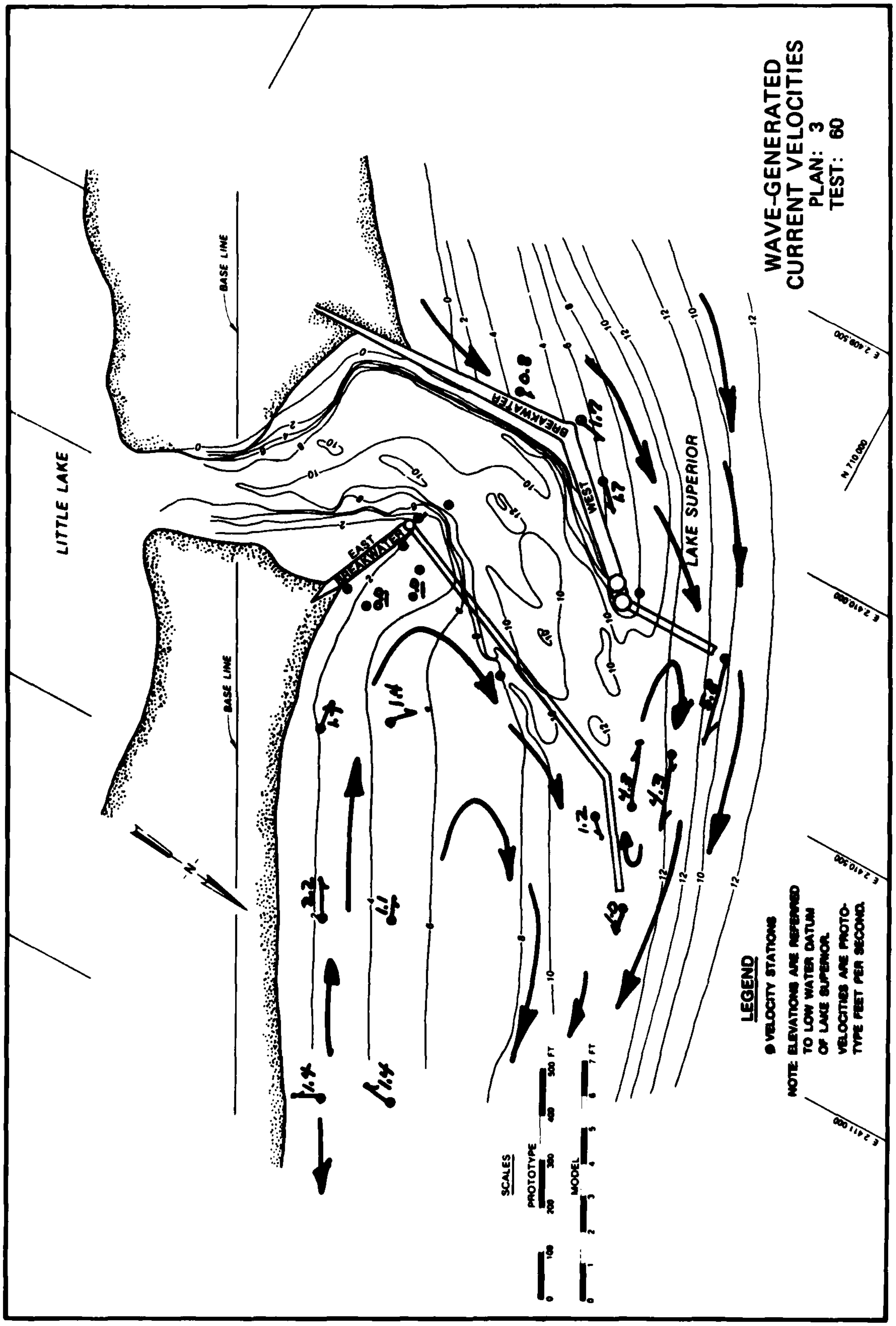

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 3
TEST: 60
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
N 710,000
E 2,409,500
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 174

CONDITION Plan 3
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 61

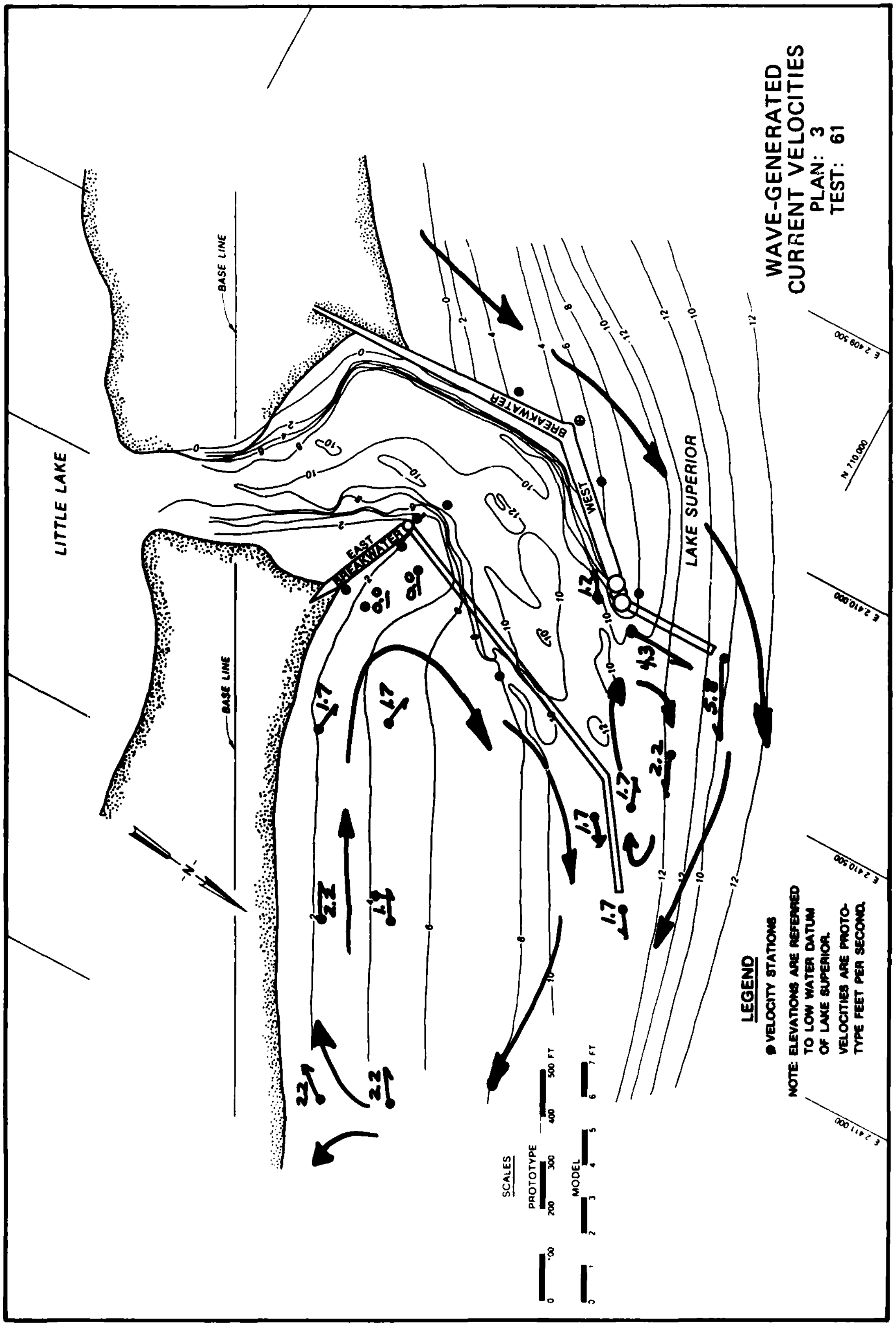
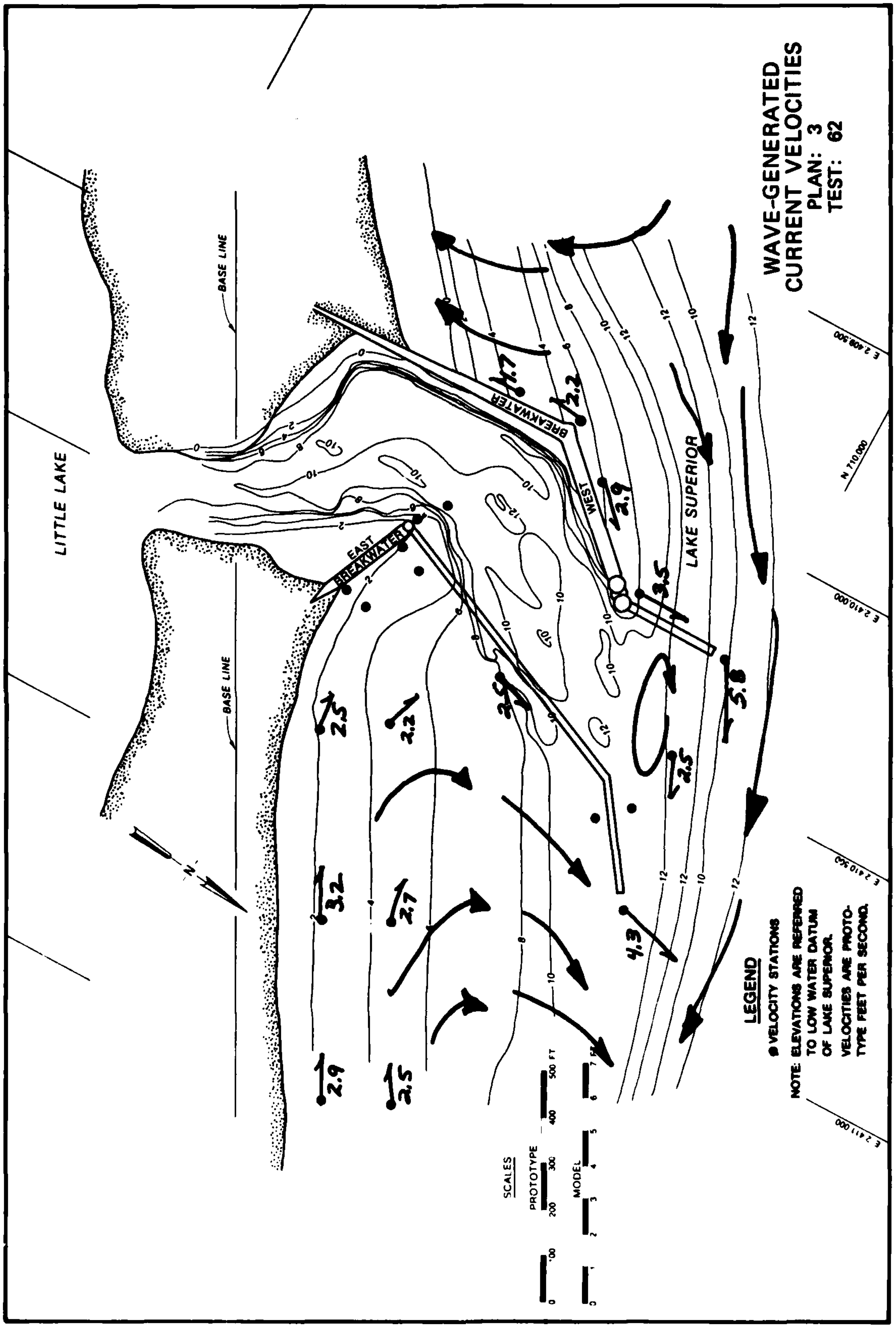

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 3
TEST: 61
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
WEST BREAKWATER
EAST BREAKWATER
N
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
N 710,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 176

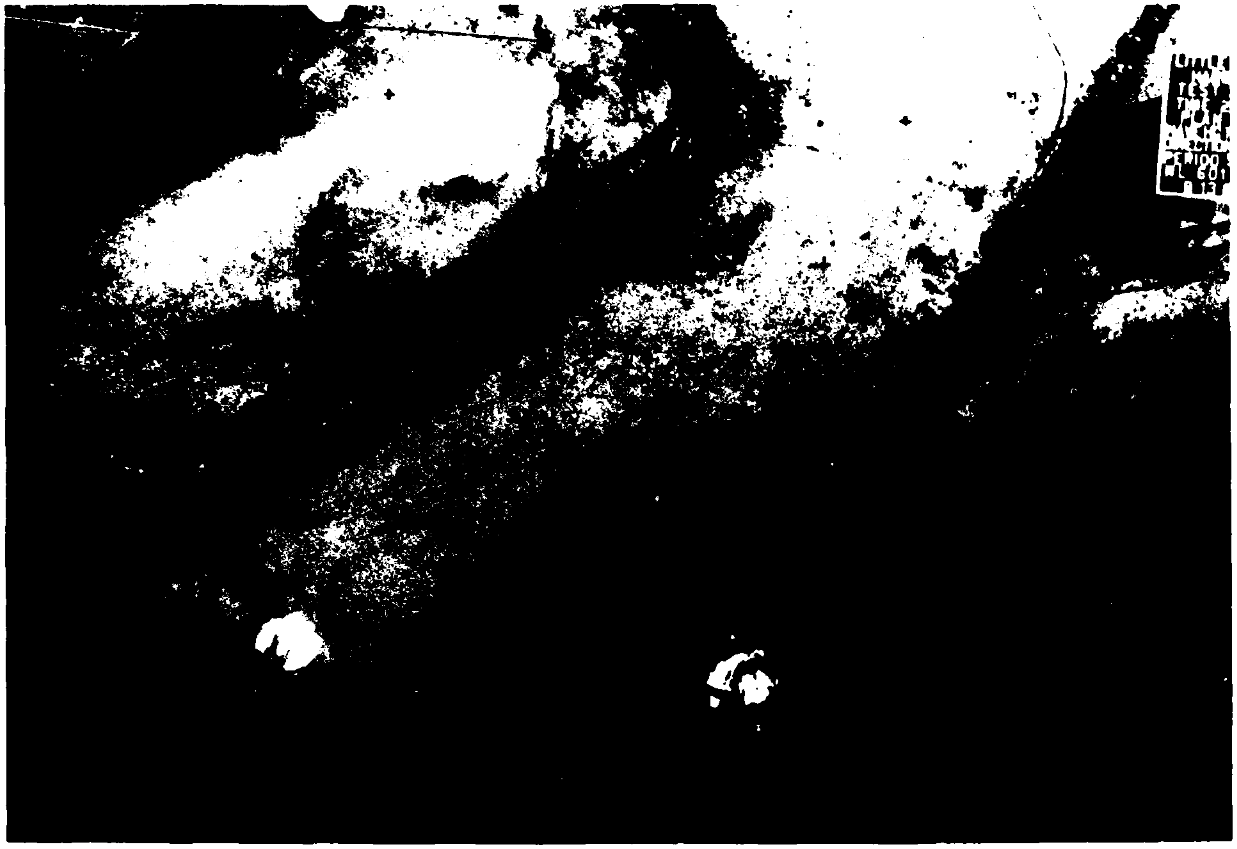
CONDITION Plan 3
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 62



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 3
TEST: 62
LITTLE LAKE
LAKE SUPERIOR
WEST
BREAKWATER
EAST
BREAKWATER
BASE LINE
BASE LINE
N 710,000
E 2,408,500
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
1.7
2.2
2.9
3.5
5.8
2.5
2.6
2.5
2.2
3.2
2.7
4.3
2.9
2.5

PLATE 178



CONDITION Plan 4
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 57

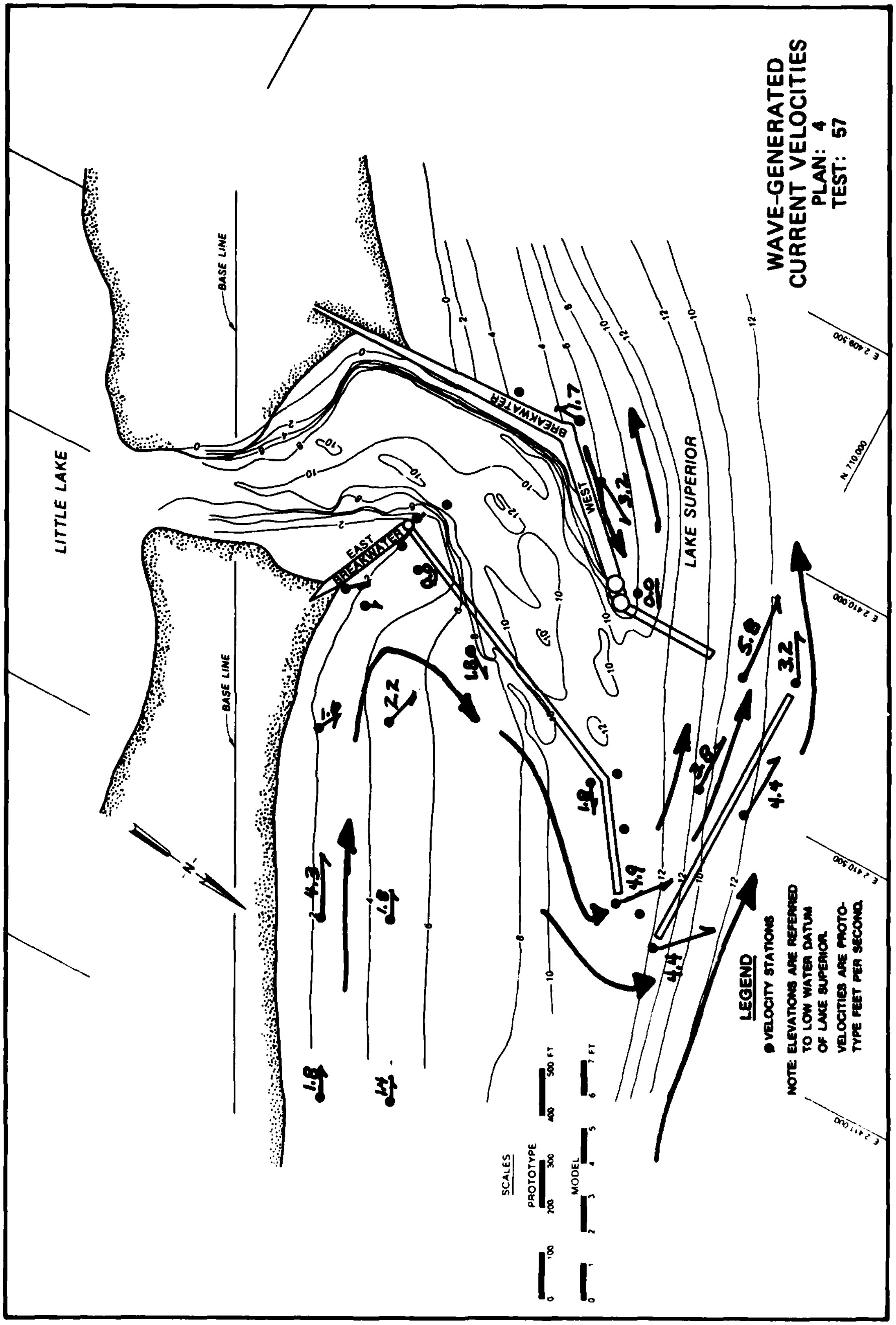
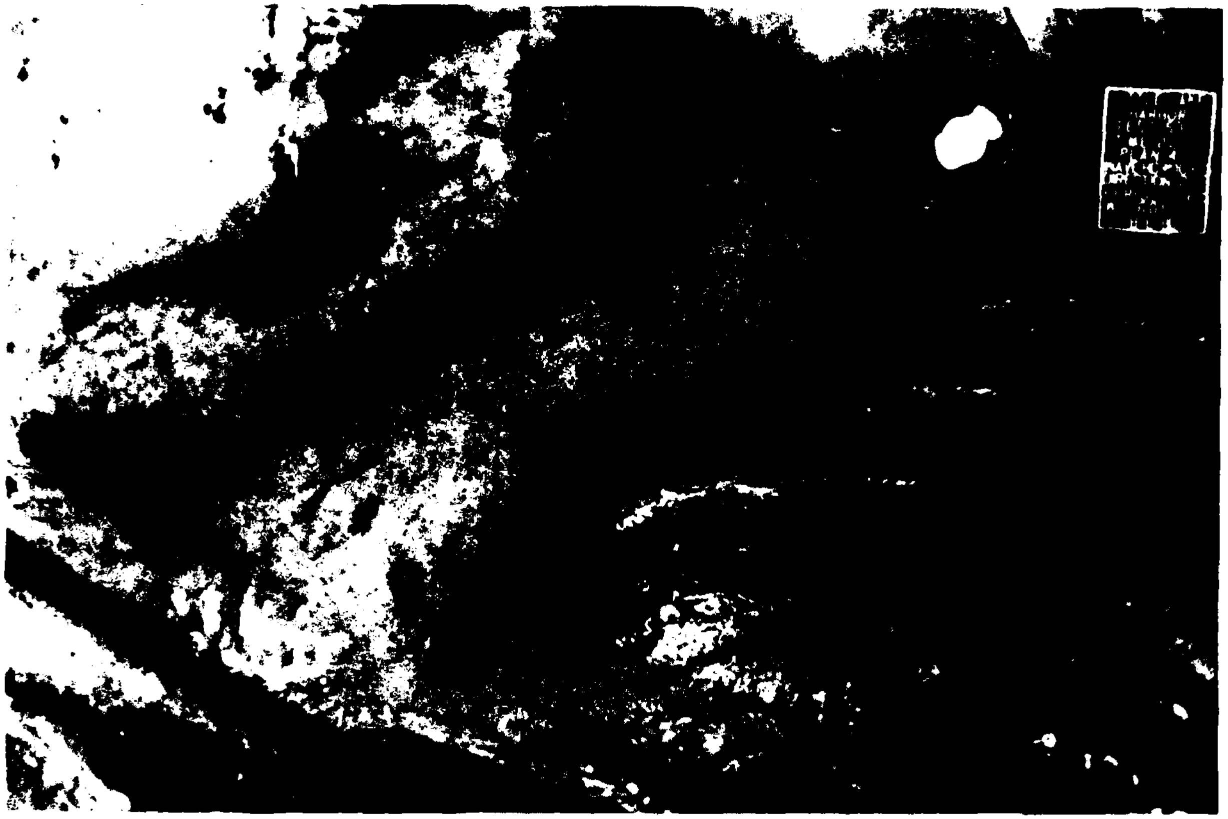

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 4
TEST: 57
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
N
N 710,000
E 2 409,500
E 2 410,000
E 2 410,500
E 2 411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 180



CONDITION Plan 4
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 53

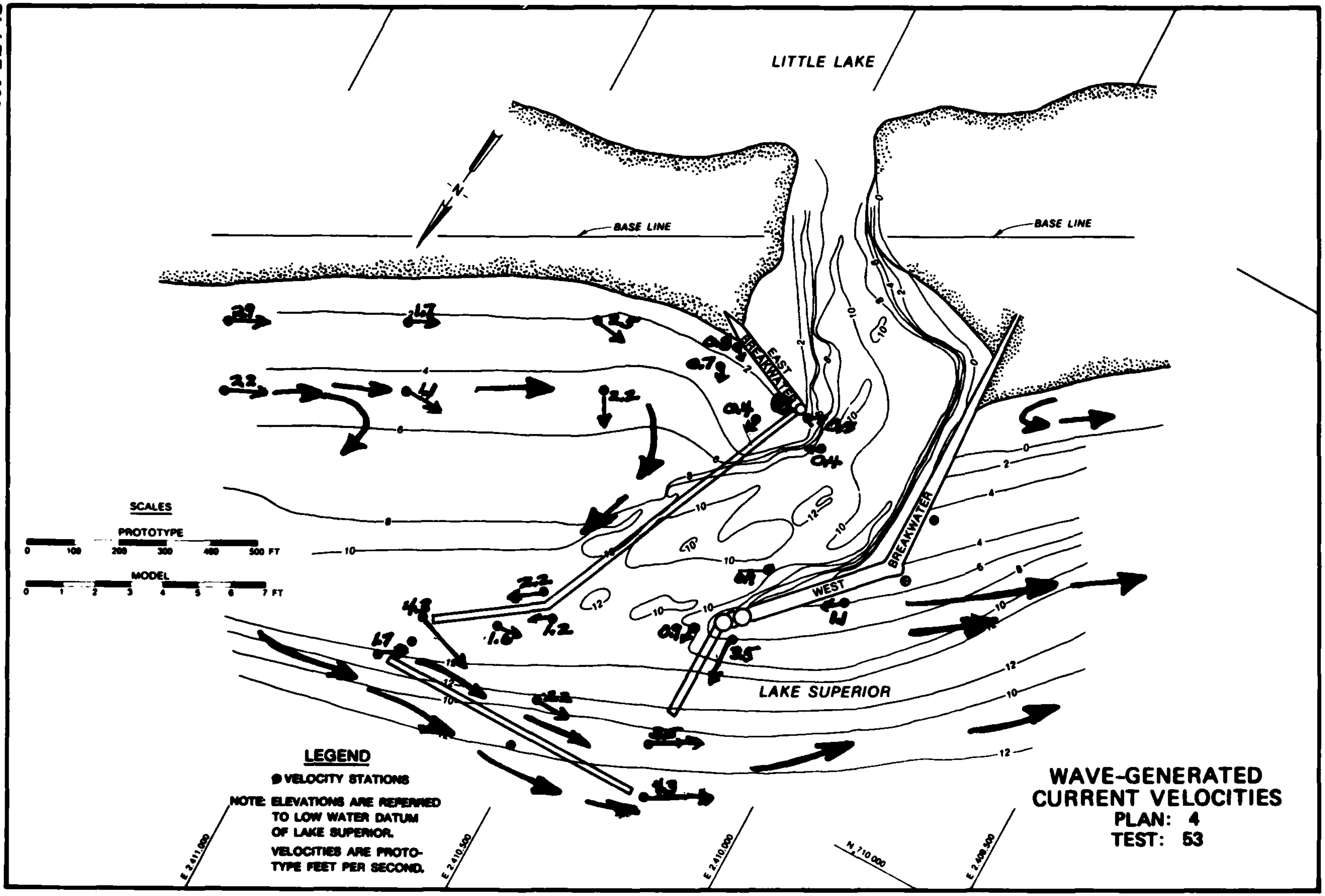
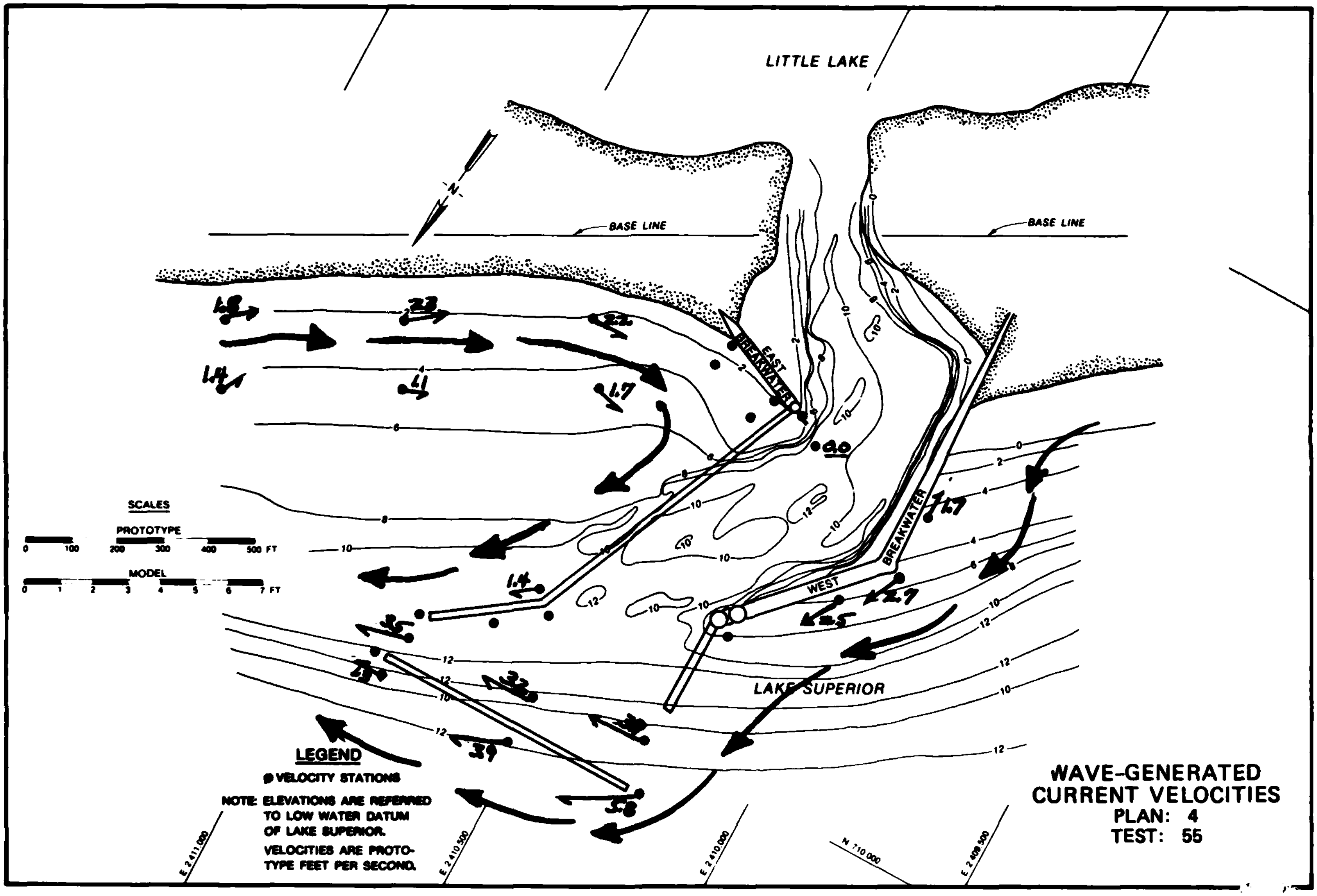

LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 4
TEST: 53

PLATE 182

CONDITION Plan 4
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 55



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 4
TEST: 55

PLATE 184

CONDITION Plan 4
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 54

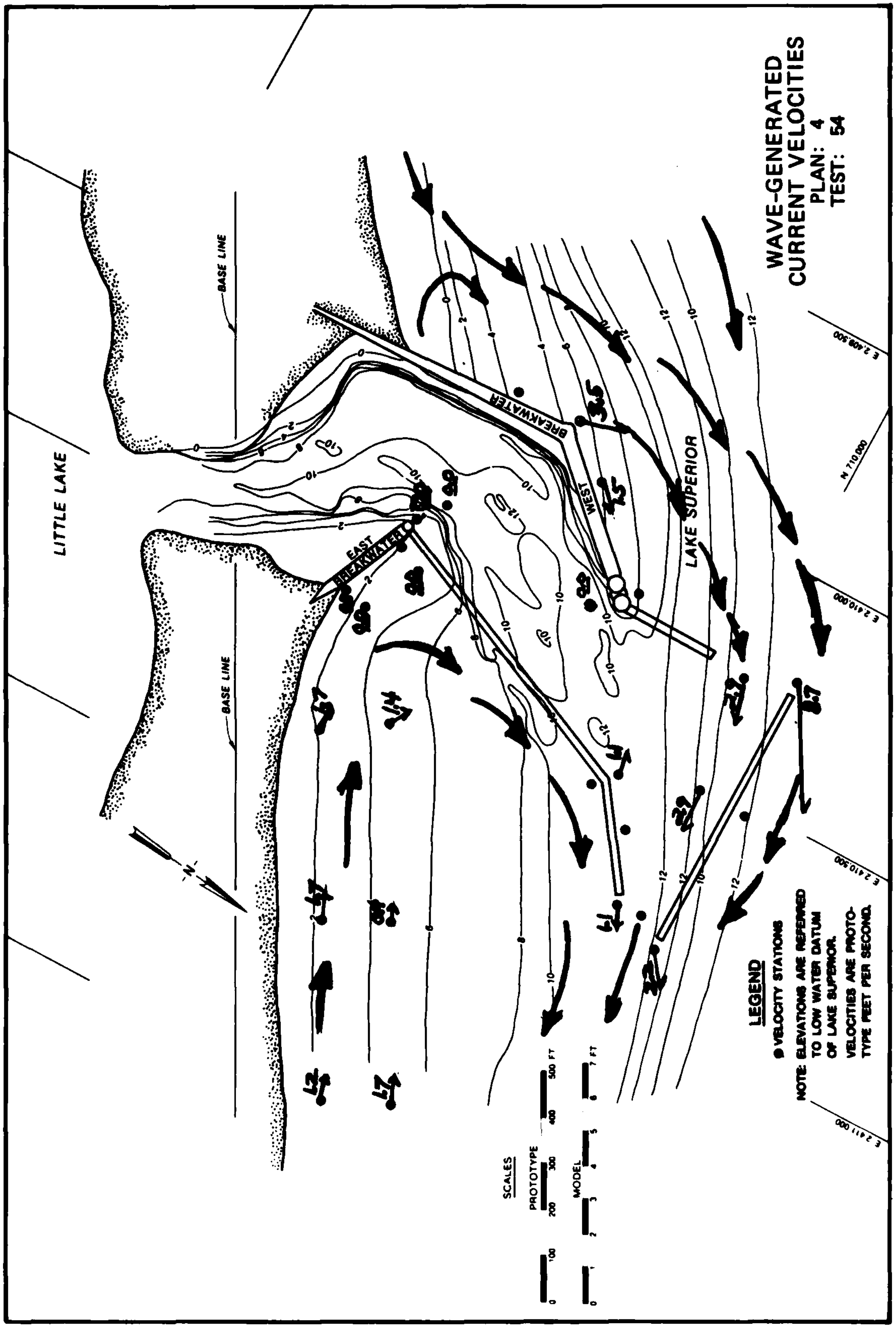

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 4
TEST: 54
LITTLE LAKE
LAKE SUPERIOR
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
N 710,000
E 2,409,500
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 186

CONDITION Plan 4
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 56

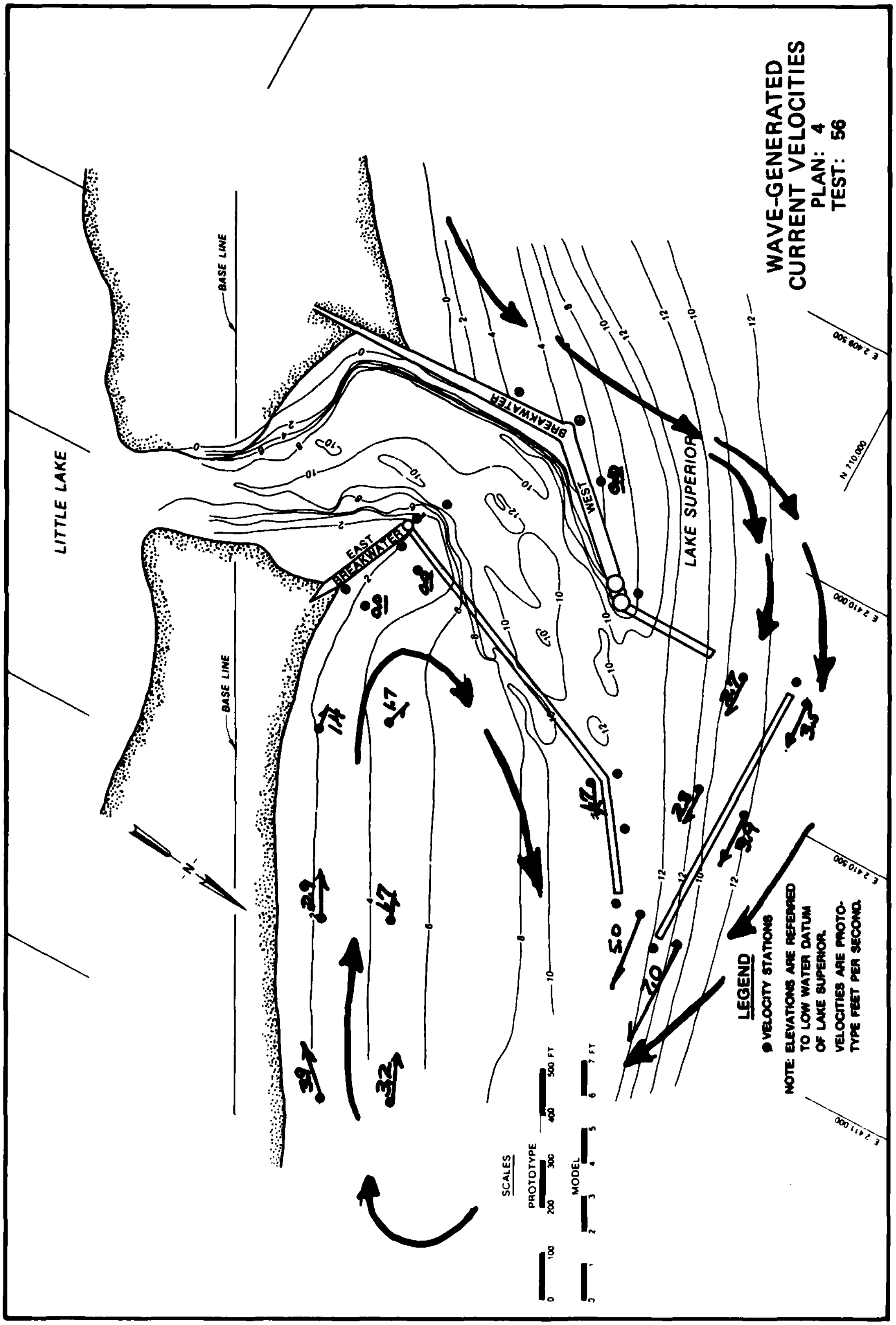
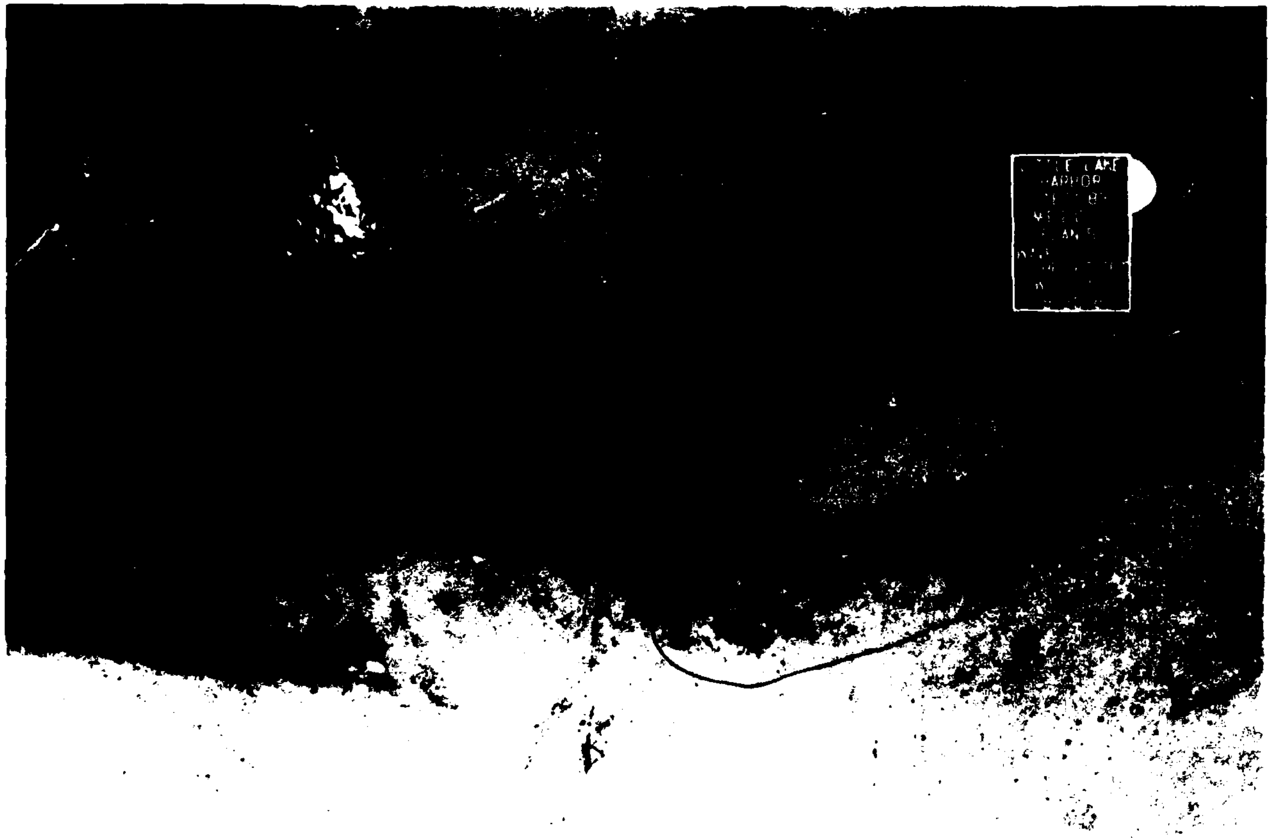

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 4
TEST: 56
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 188



CONDITION Plan 5
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 83

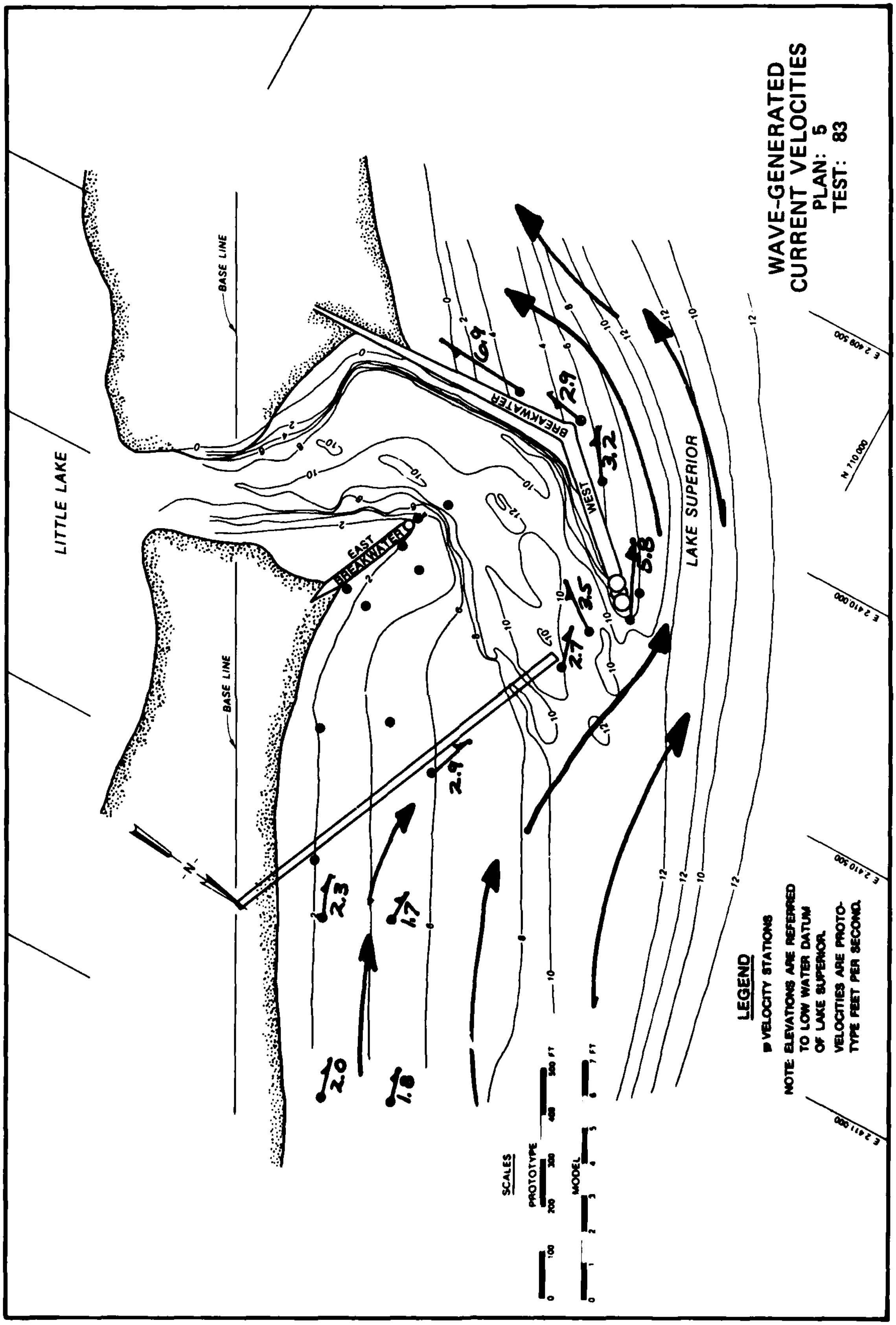

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 5
TEST: 83
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
6.9
2.9
3.2
5.8
3.5
2.7
2.9
2.3
1.7
2.0
1.8
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 190

CONDITION Plan 5
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 84

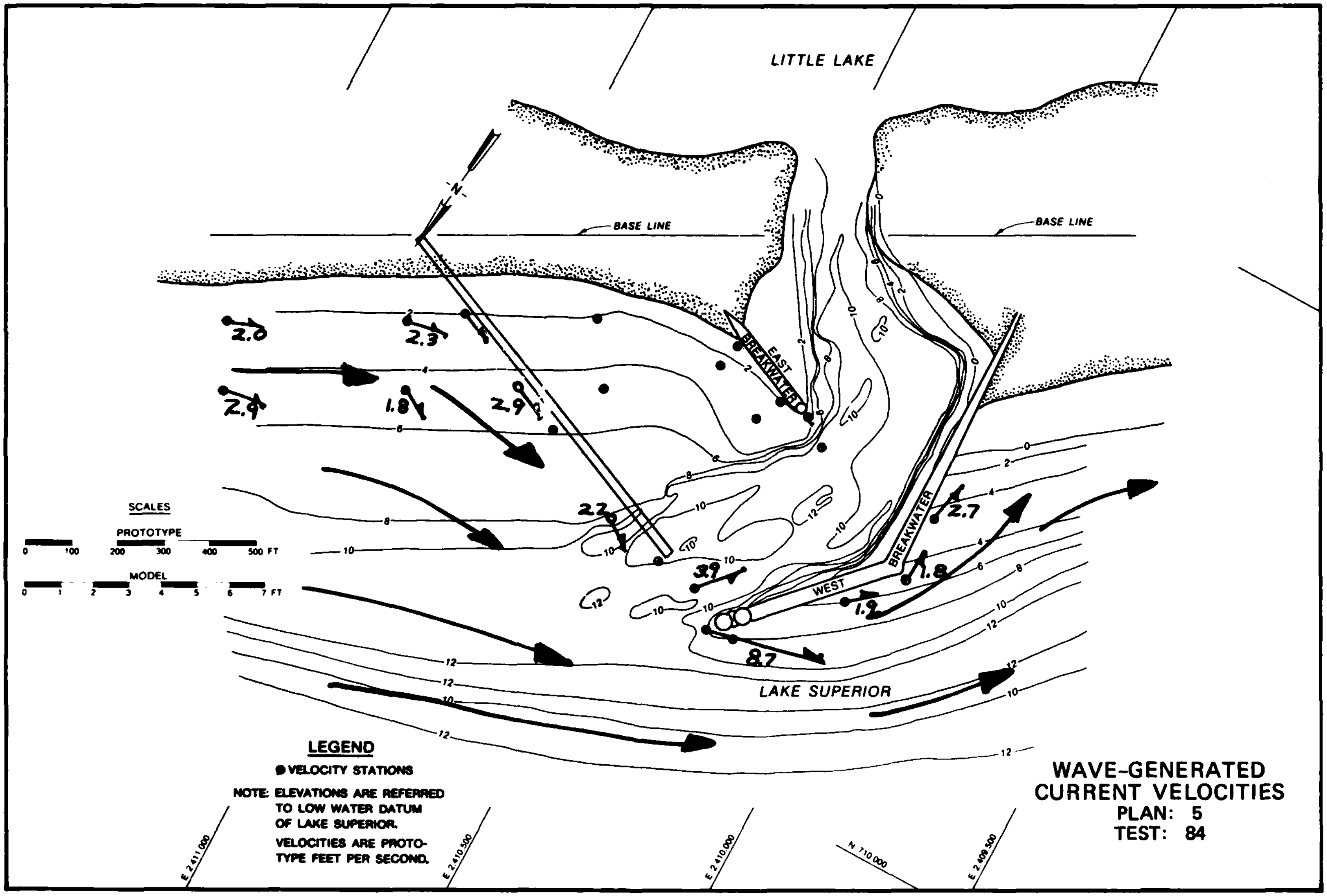
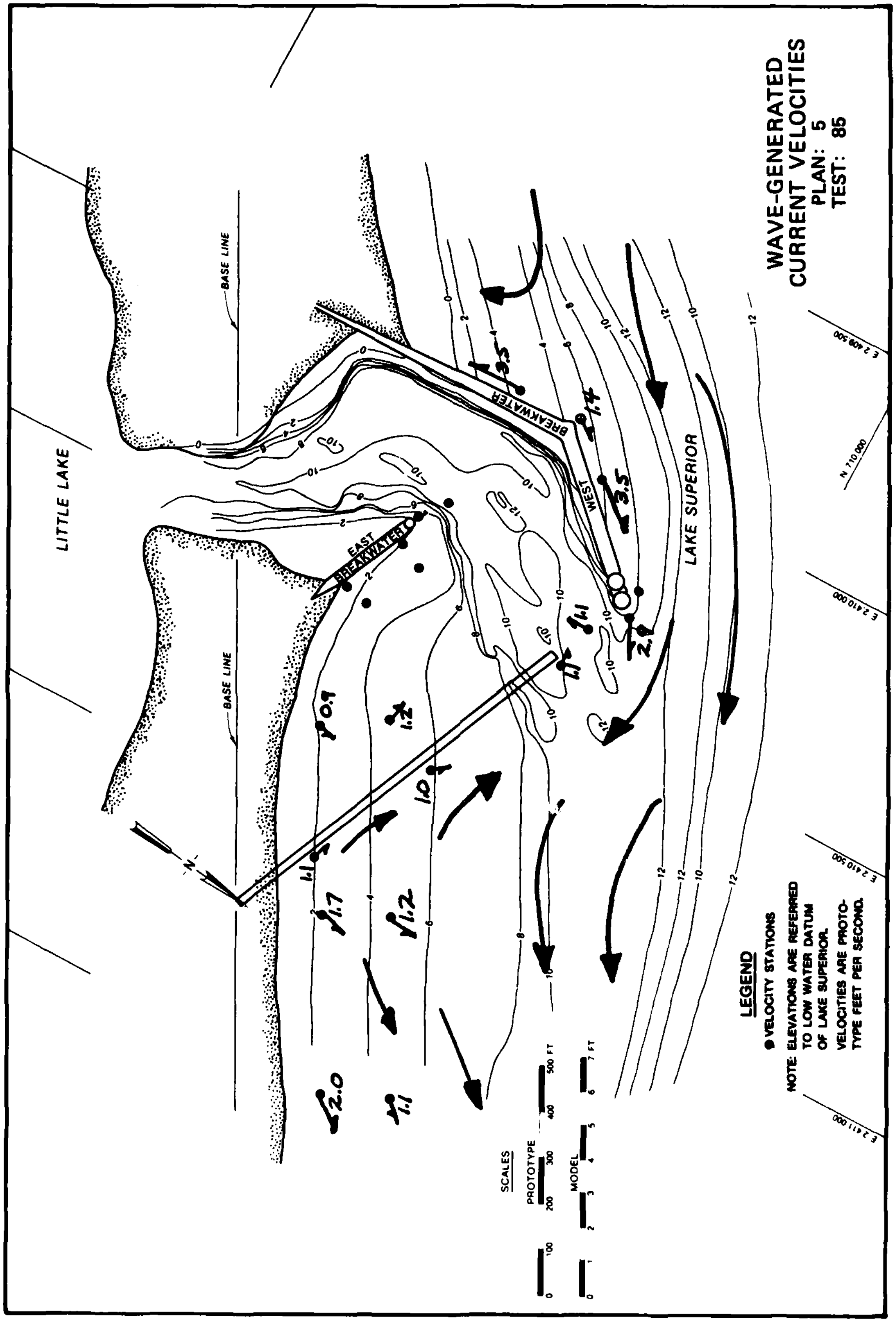

LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
2.0
2.3
2.9
1.8
2.9
2.2
3.9
8.7
1.9
1.8
2.7
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2 411 000
E 2 410 500
E 2 410 000
N 710 000
E 2 409 500
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 5
TEST: 84

PLATE 192

CONDITION Plan 5
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0

SHOALING TEST 85

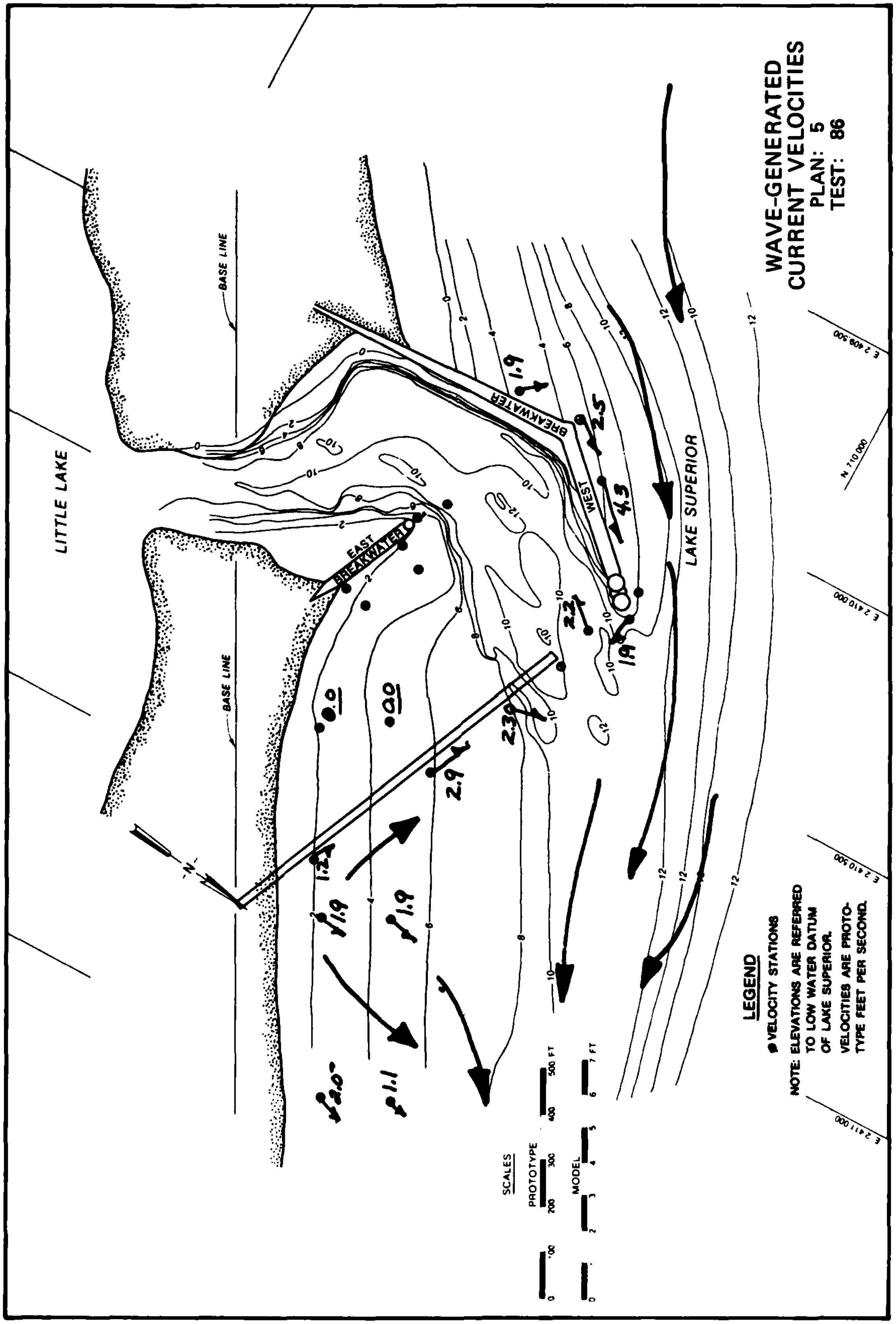


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 5
TEST: 85
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
N 710 000
3.5
1.4
3.5
2.8
1.1
1.1
0.9
1.2
1.0
1.1
1.7
1.2
2.0
1.1

PLATE 194

CONDITION Plan 5
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0

SHOALING TEST 86



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 5
TEST: 86
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
N 710 000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

CONDITION Plan 5
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0

SHOALING TEST 87

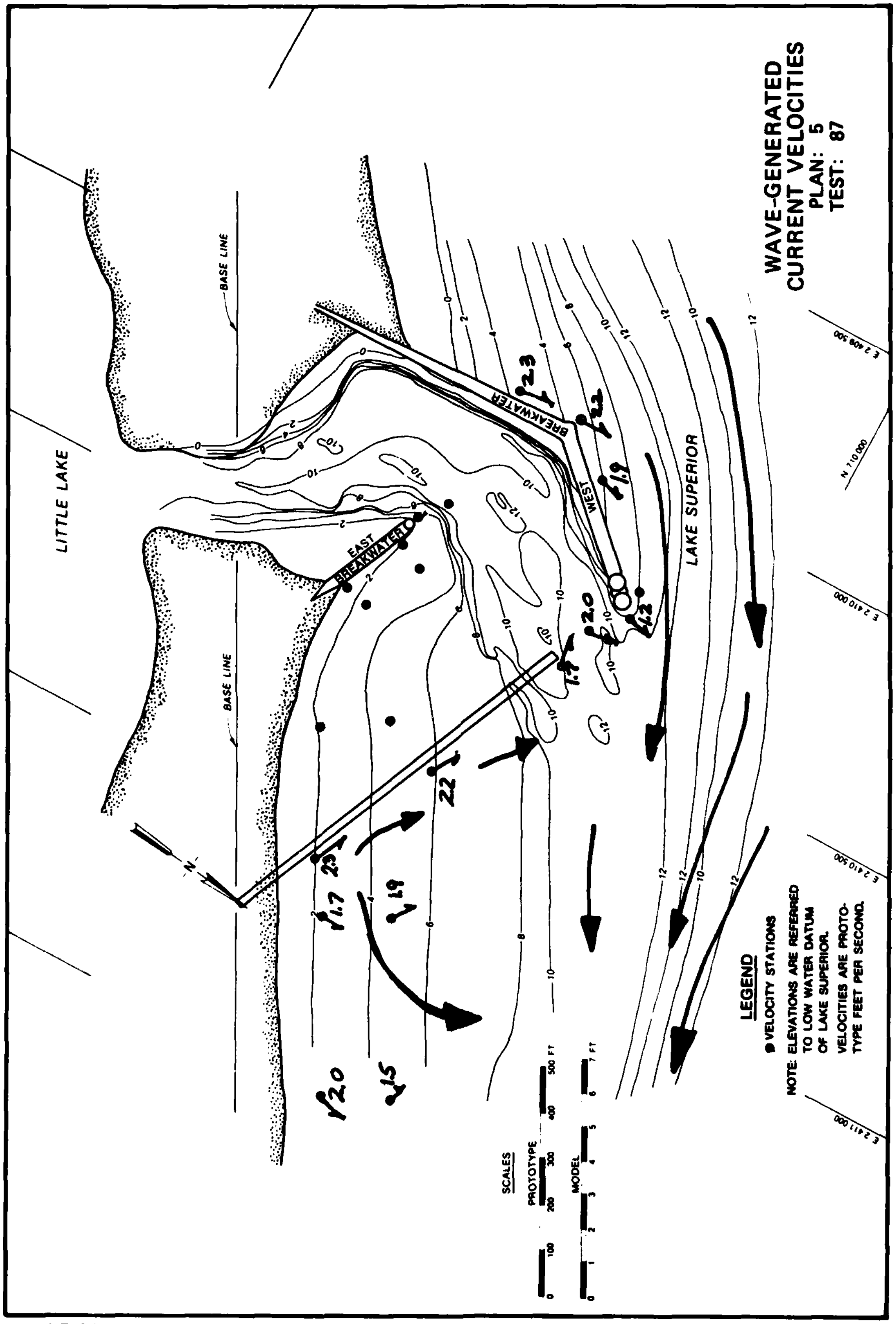

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 5
TEST: 87
LITTLE LAKE
LAKE SUPERIOR
WEST
BREAKWATER
EAST
BREAKWATER
BASE LINE
BASE LINE
N 710,000
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
2.3
2.2
1.9
2.0
1.2
1.7
2.2
2.3
1.7
1.9
2.0
1.5

PLATE 198

CONDITION Plan 5
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.6 ft

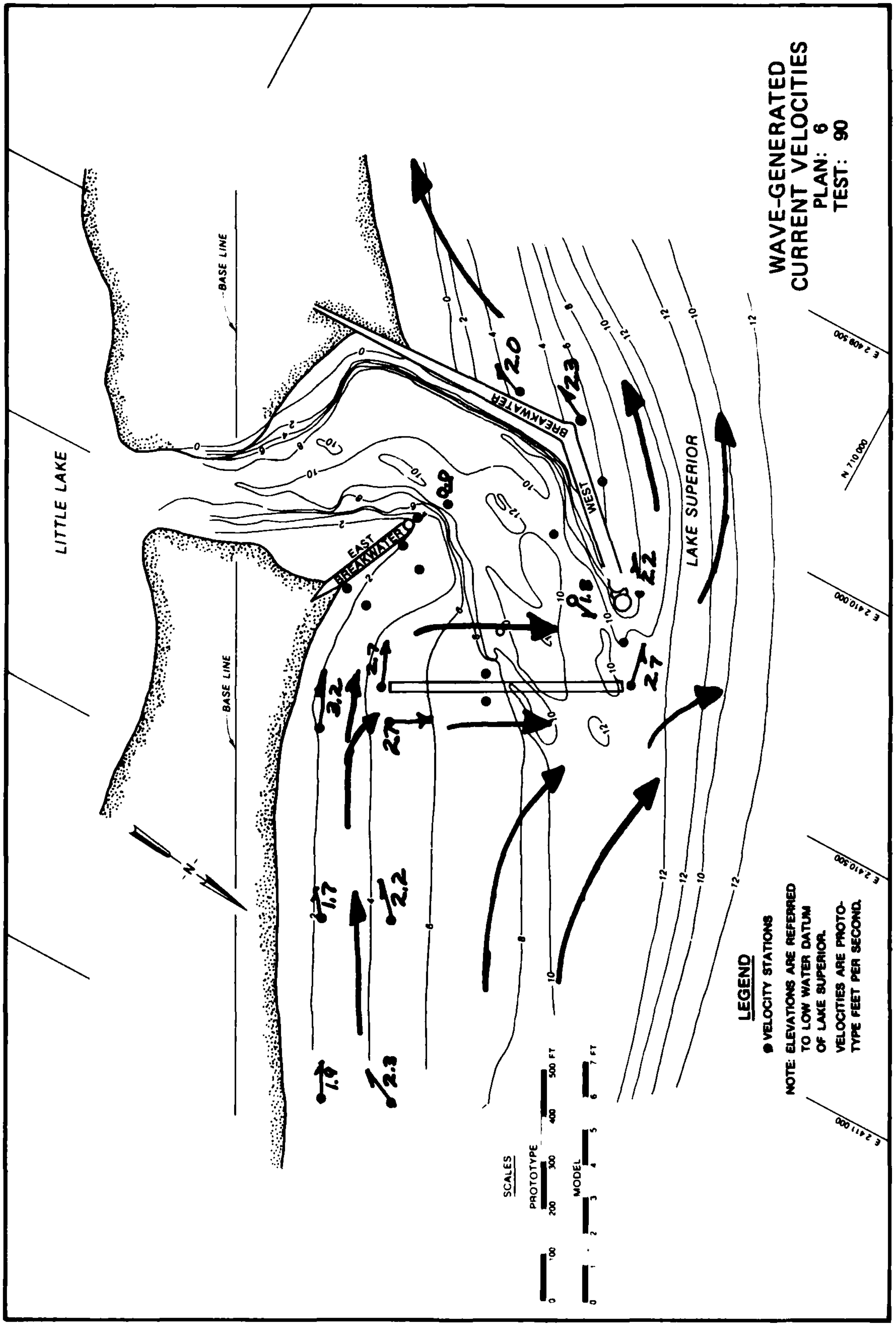
SHOALING TEST 8 8

CONDITION Plan 5
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0.6 ft

SHOALING TEST 89

CONDITION Plan 6
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST **90**



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 6
TEST: 90
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
E 2 409 500
N 710 000
E 2 410 000
E 2 410 500
E 2 411 000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 202

CONDITION Plan 6
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST 91

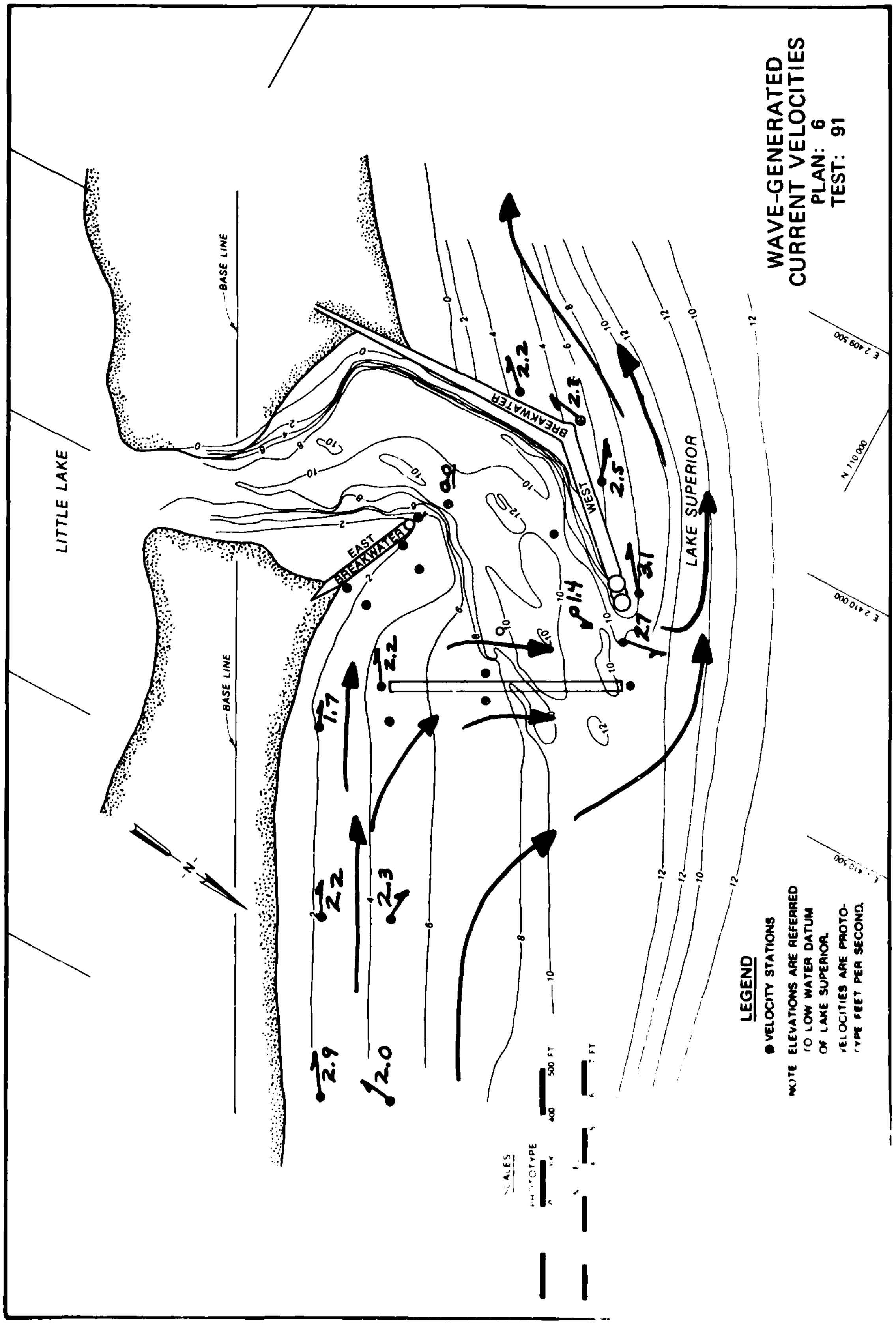
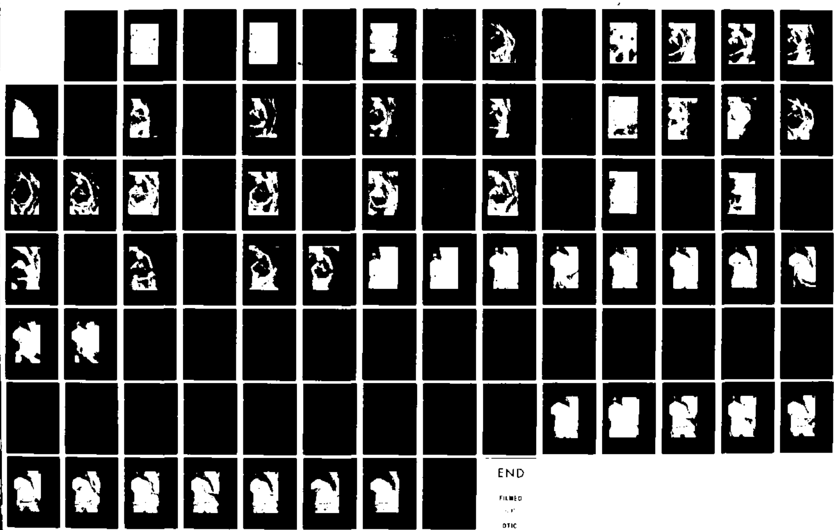
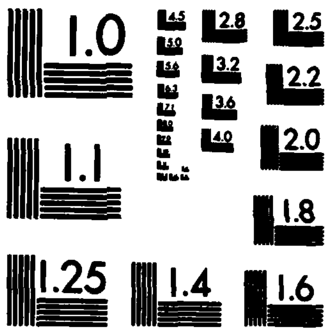

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 6
TEST: 91
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
● VELOCITY STATIONS
NOTE ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
N 710 000
E 2 409 500
E 2 410 000

PLATE 204

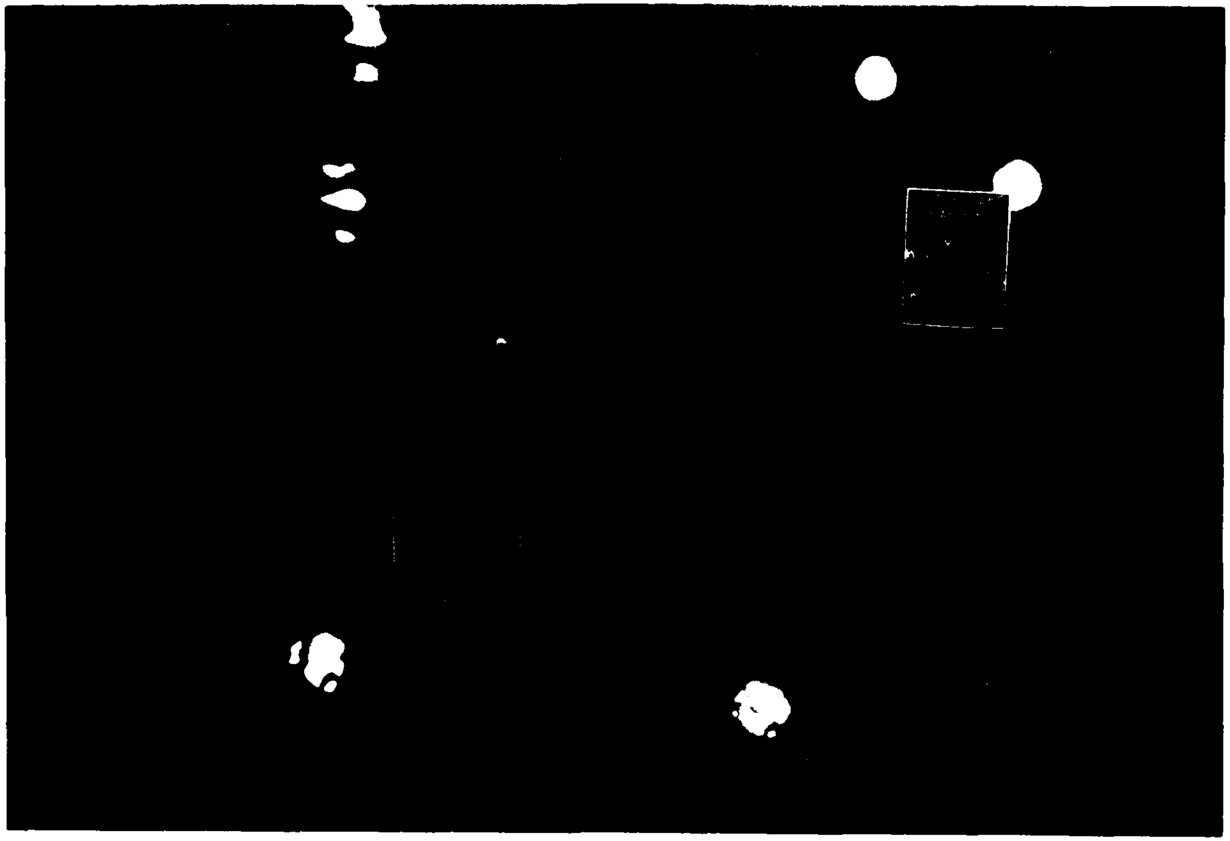
AD-A120 776 PREVENTION OF SHOALING AT LITTLE LAKE HARBOR MICHIGAN 4/4
HYDRAULIC MODEL INV..(U) ARMY ENGINEER WATERWAYS
EXPERIMENT STATION VICKSBURG MS HYDRA..
UNCLASSIFIED W C SEABERGH ET AL. JUL 82 WES/TR/HL-82-16 F/G 13/2 NL



END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



CONDITION Plan 6
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST **92**

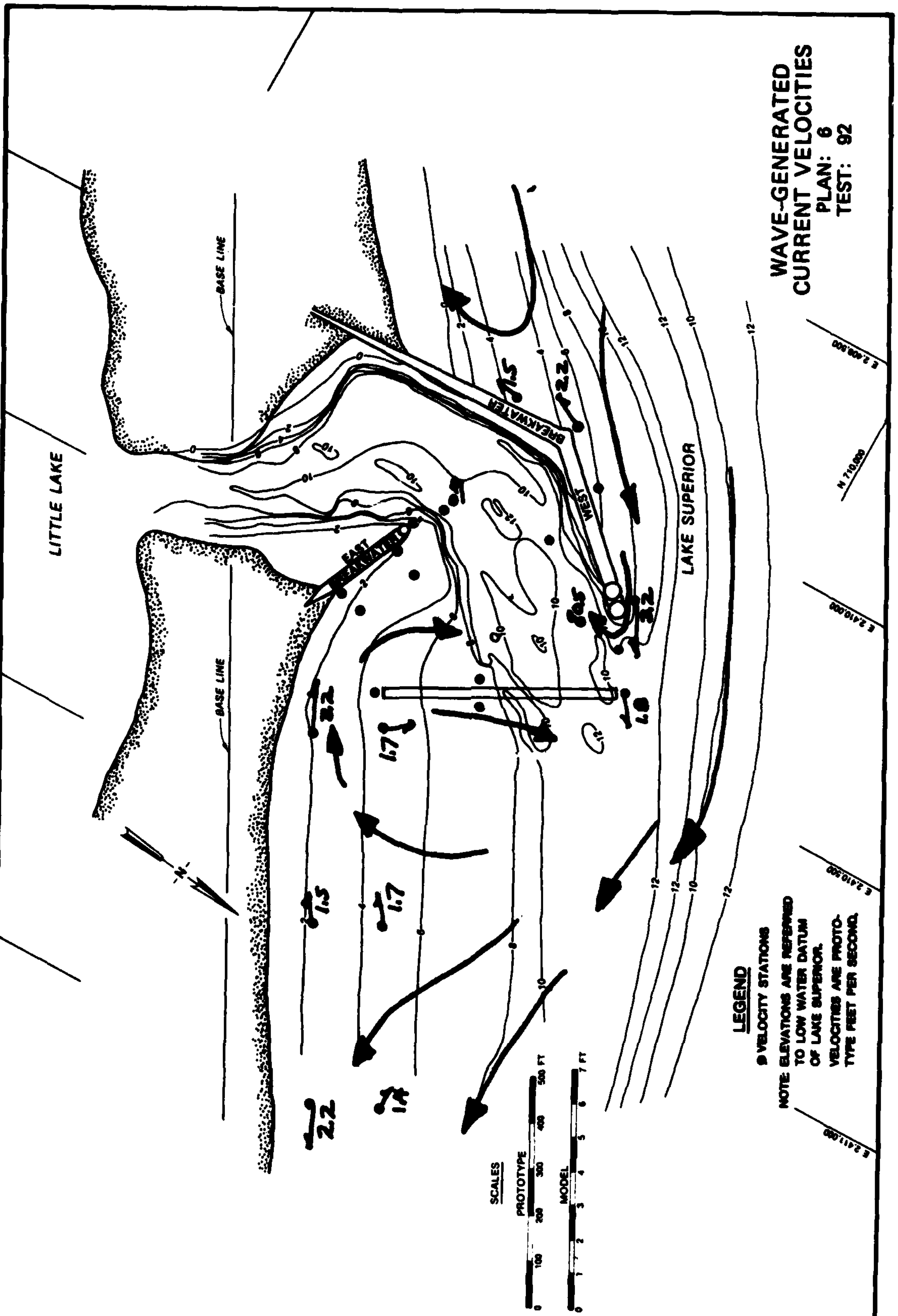
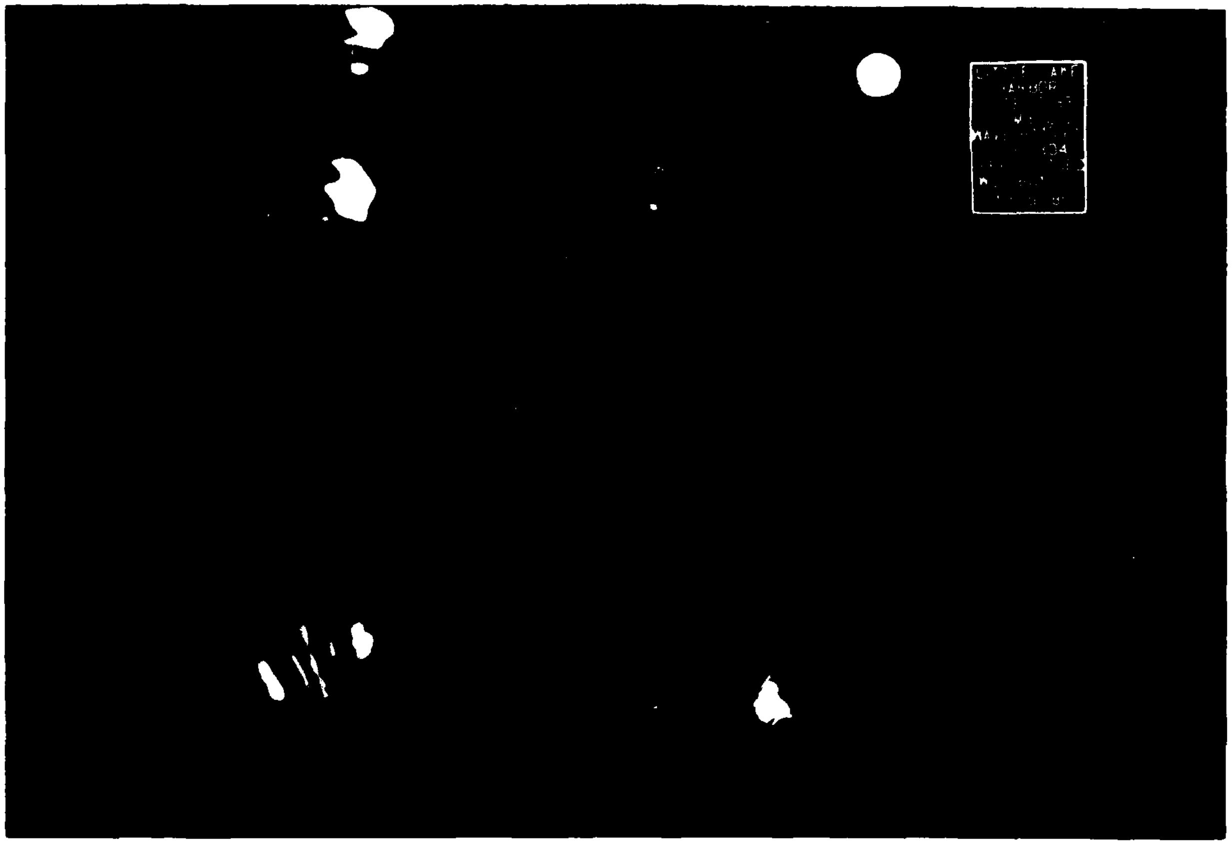
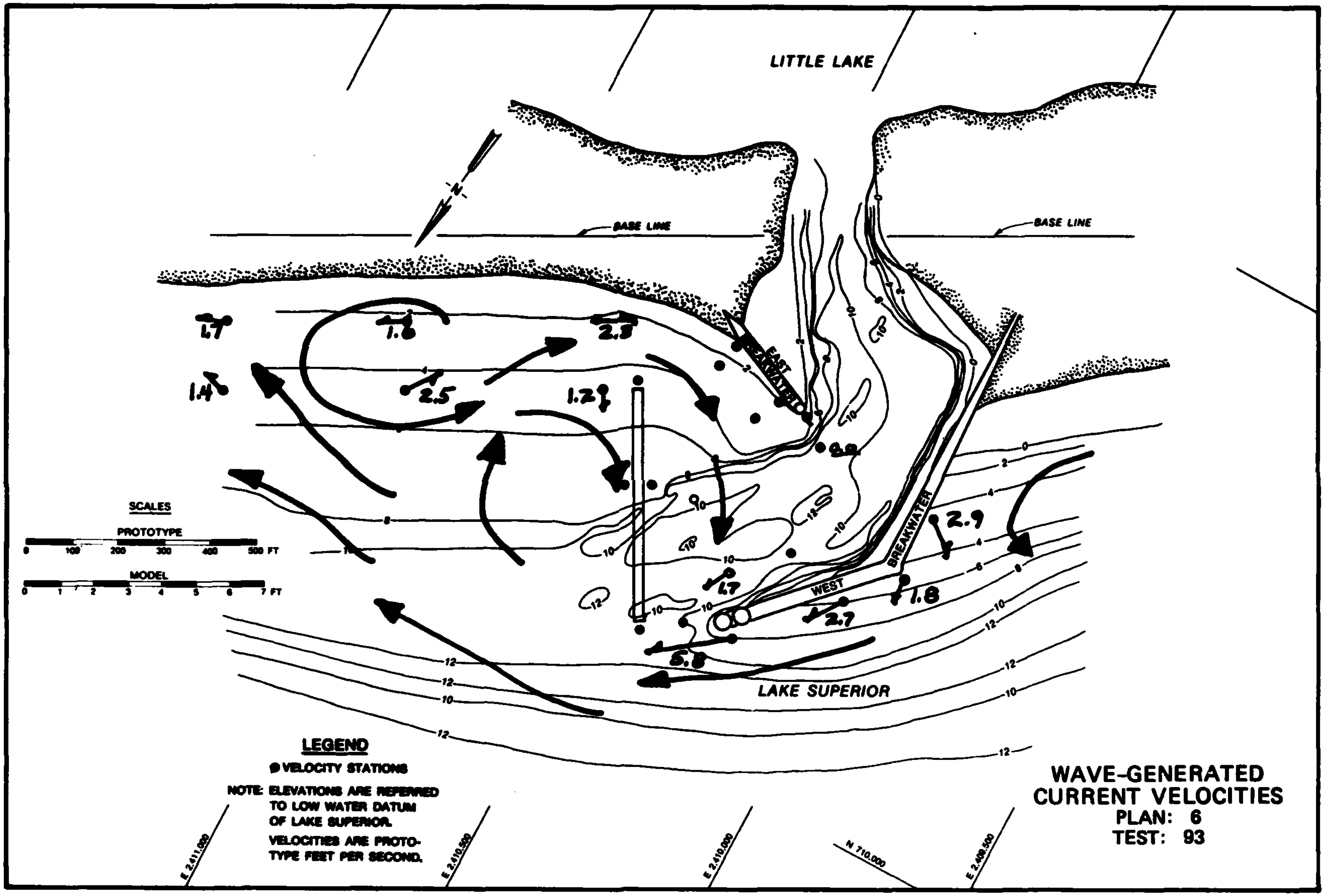

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 6
TEST: 92
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
E 2,409,500
N 710,000
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

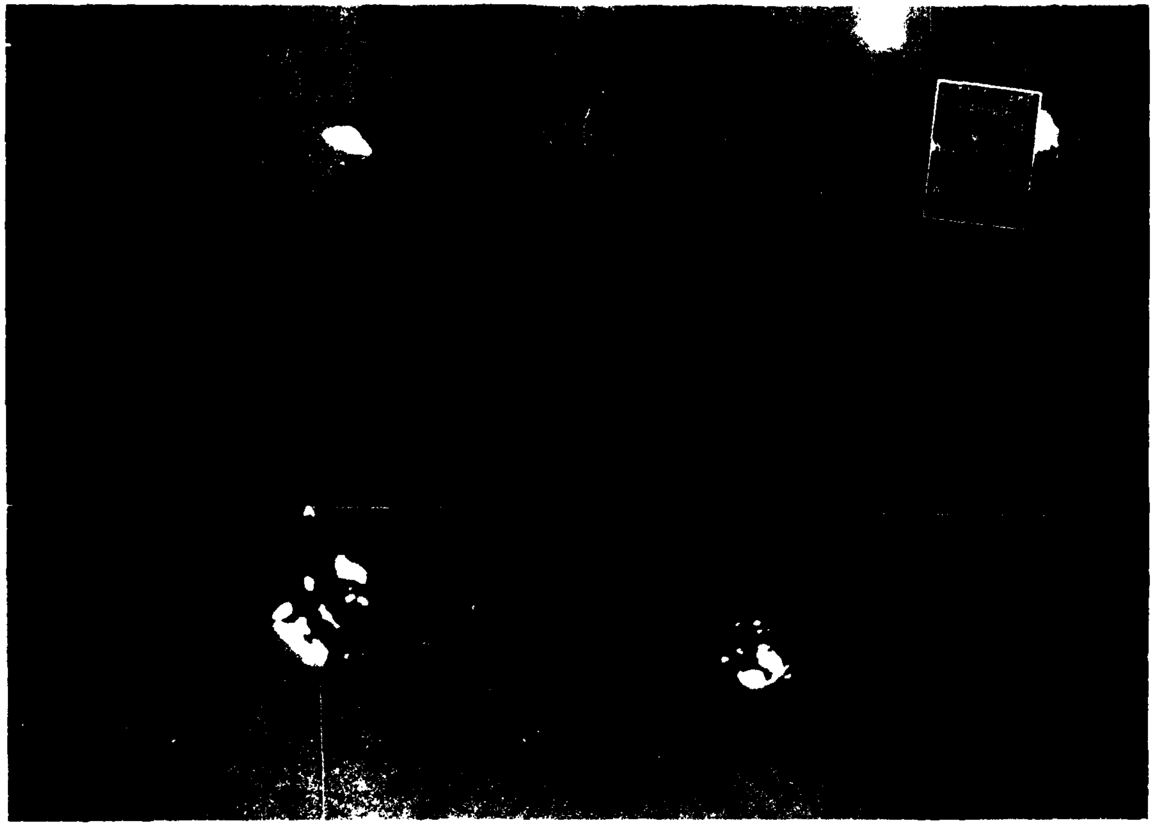
PLATE 206



CONDITION Plan 6
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

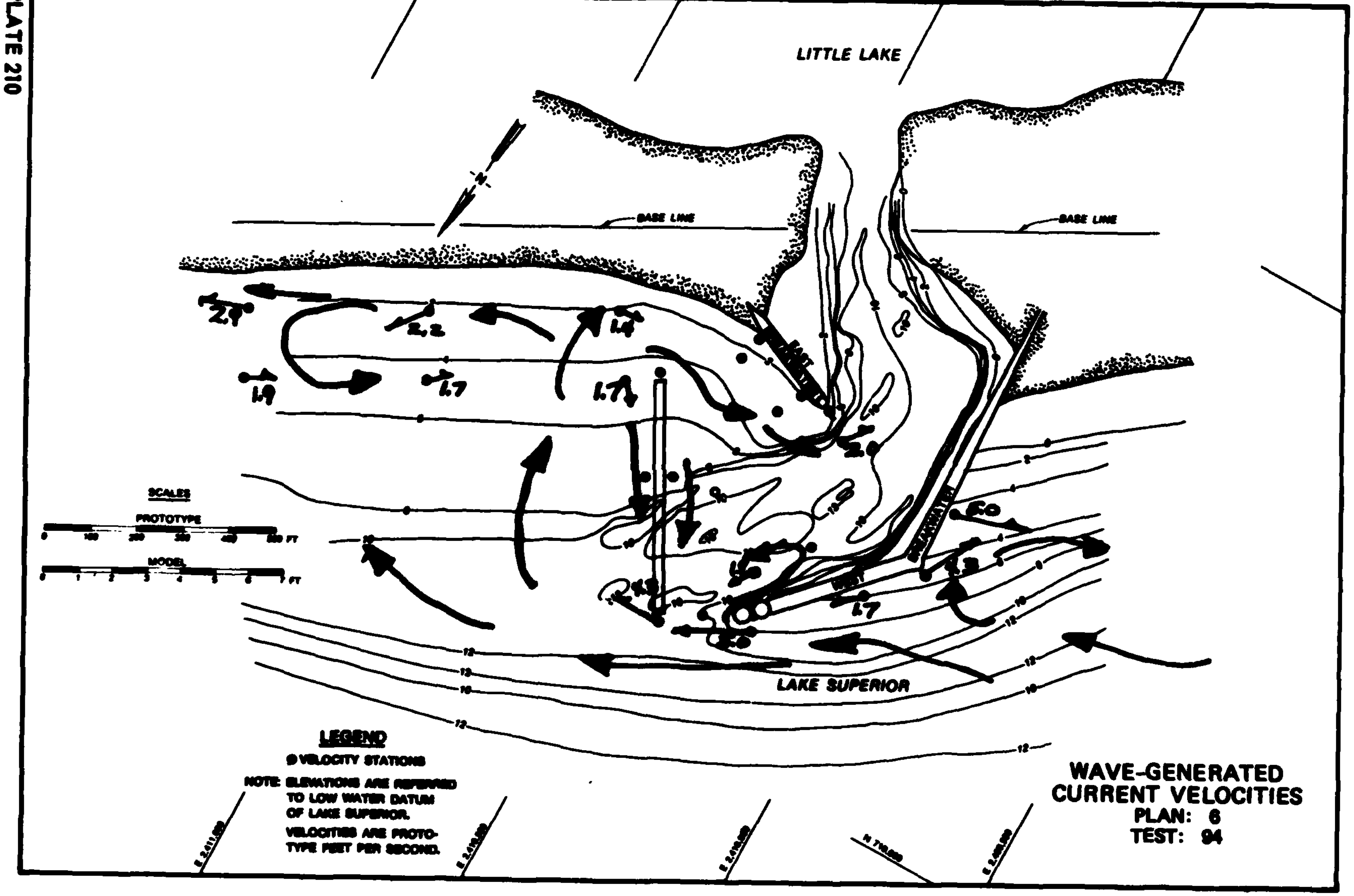
SHOALING TEST 93


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 6
TEST: 93
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
1.7
1.4
1.6
2.5
2.3
1.2
2.9
1.8
2.7
1.7
5.8



CONDITION Plan 6
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0.0

SHOALING TEST **94**



LITTLE LAKE
BASE LINE
BASE LINE
N
LAKE SUPERIOR
2.9
2.2
1.4
1.9
1.7
1.7
1.7
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 6
TEST: 94

PLATE 210

CONDITION Plan 7
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 100

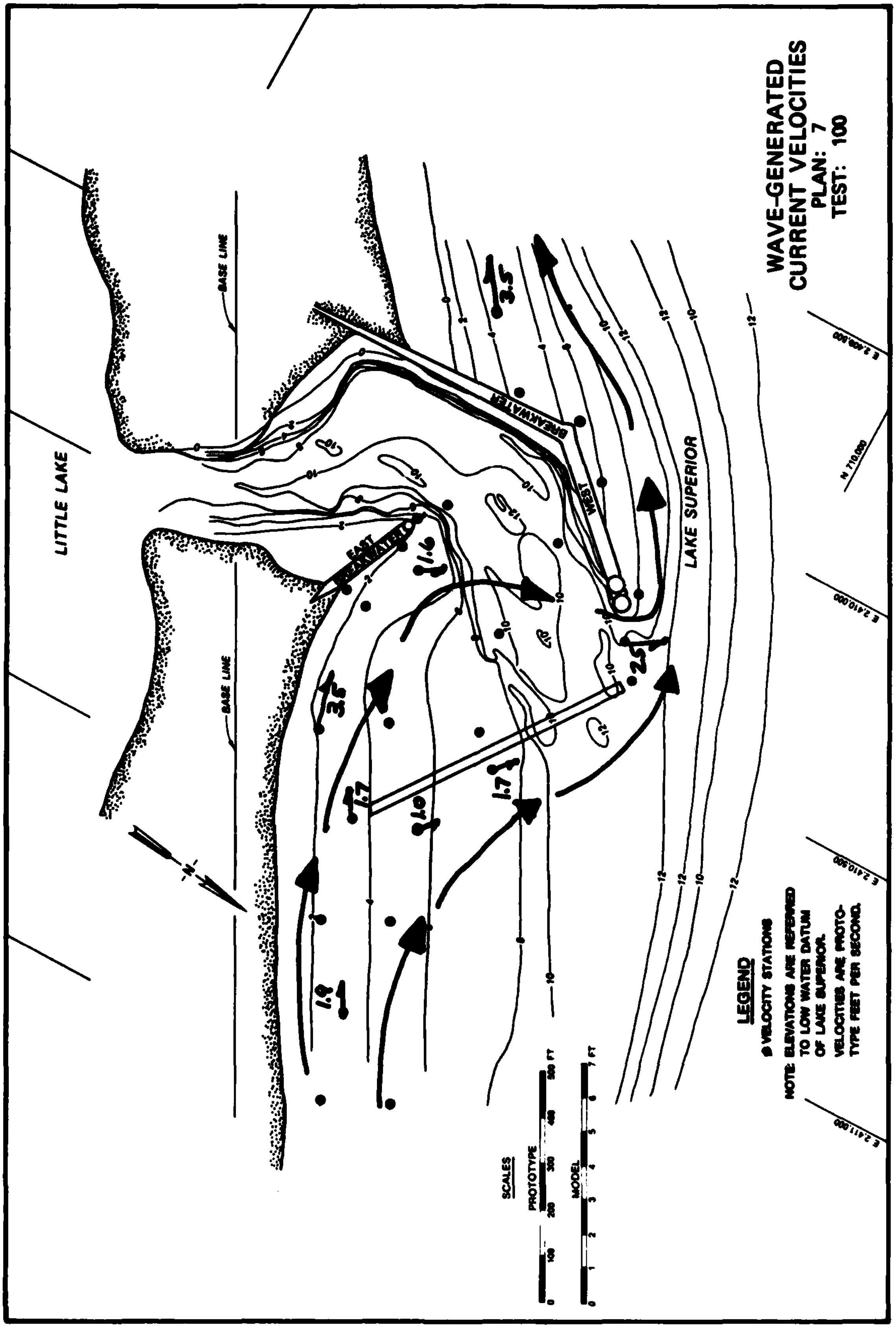
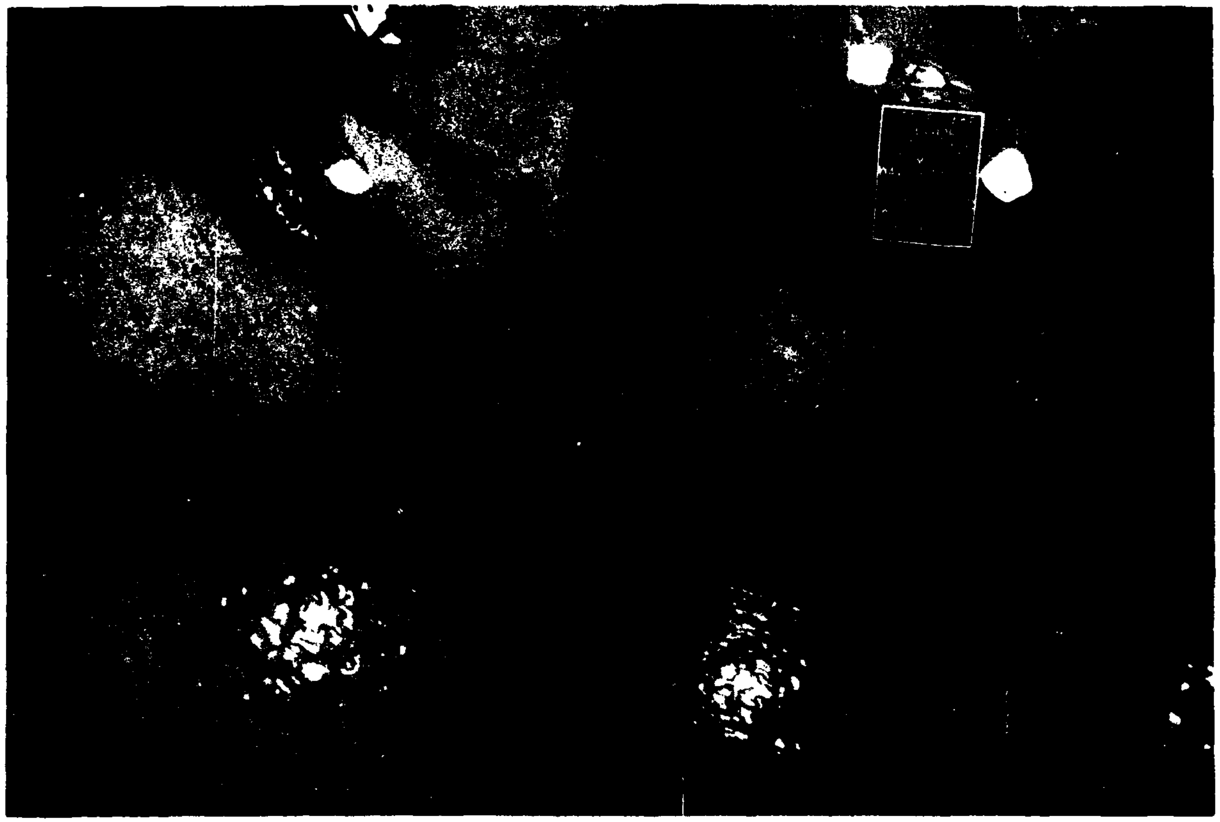
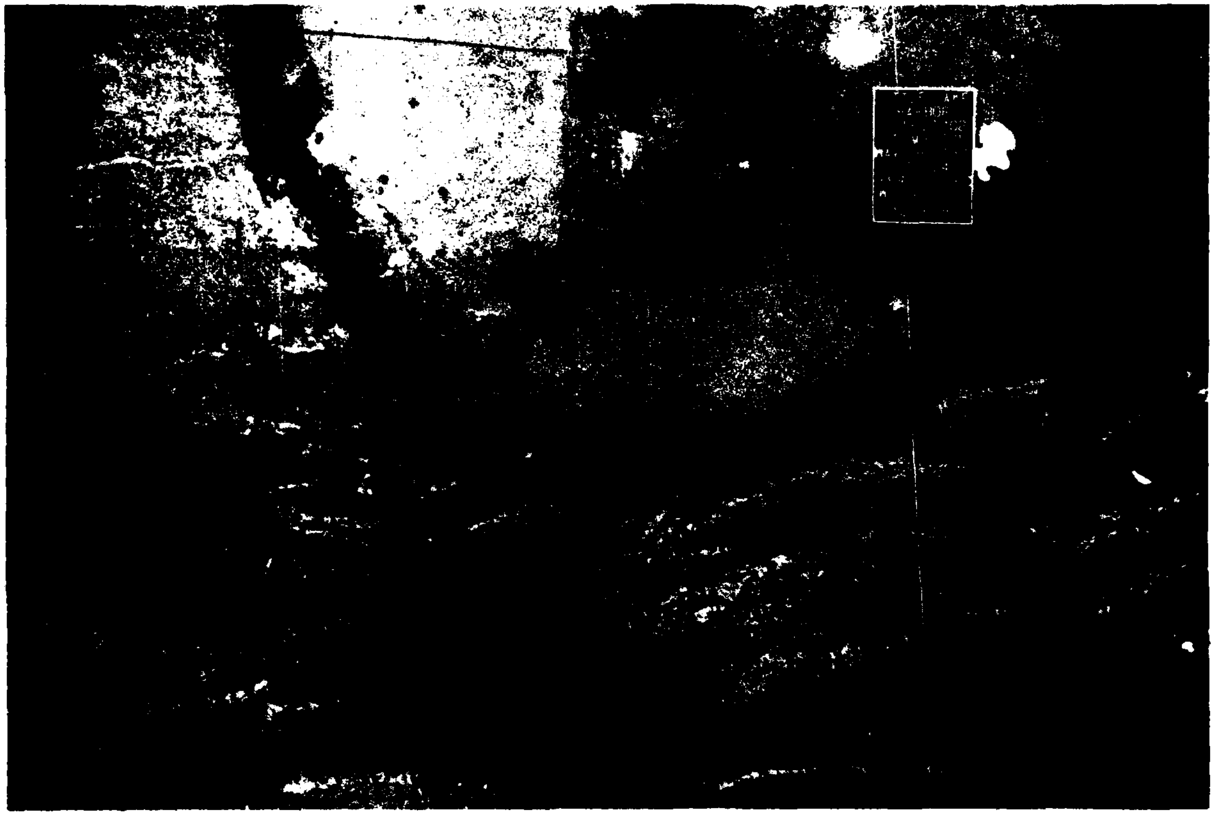

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 7
TEST: 100
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
E 2,409,500
N 710,000
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 212



CONDITION Plan 7
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST 101



CONDITION Plan 7
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

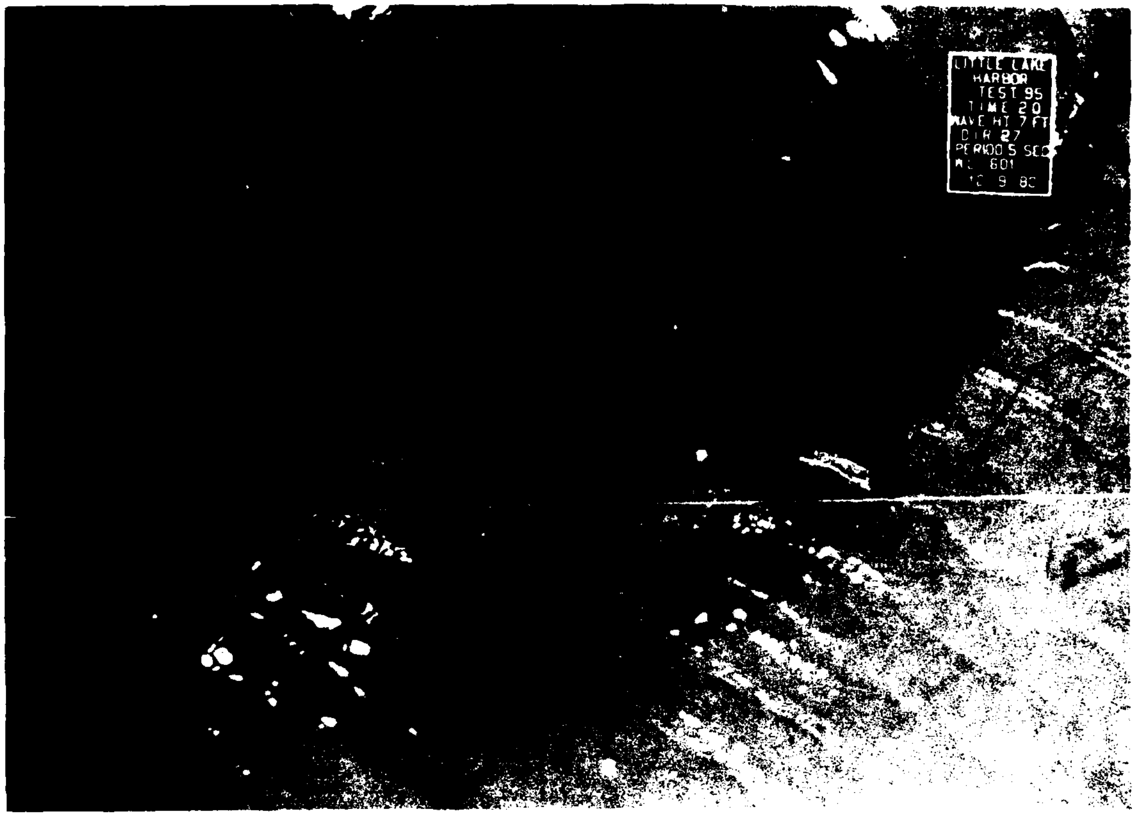
SHOALING TEST **102**

CONDITION Plan 7
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST **103**

CONDITION Plan 7
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0.0

SHOALING TEST 104



CONDITION Plan 8
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST **95**

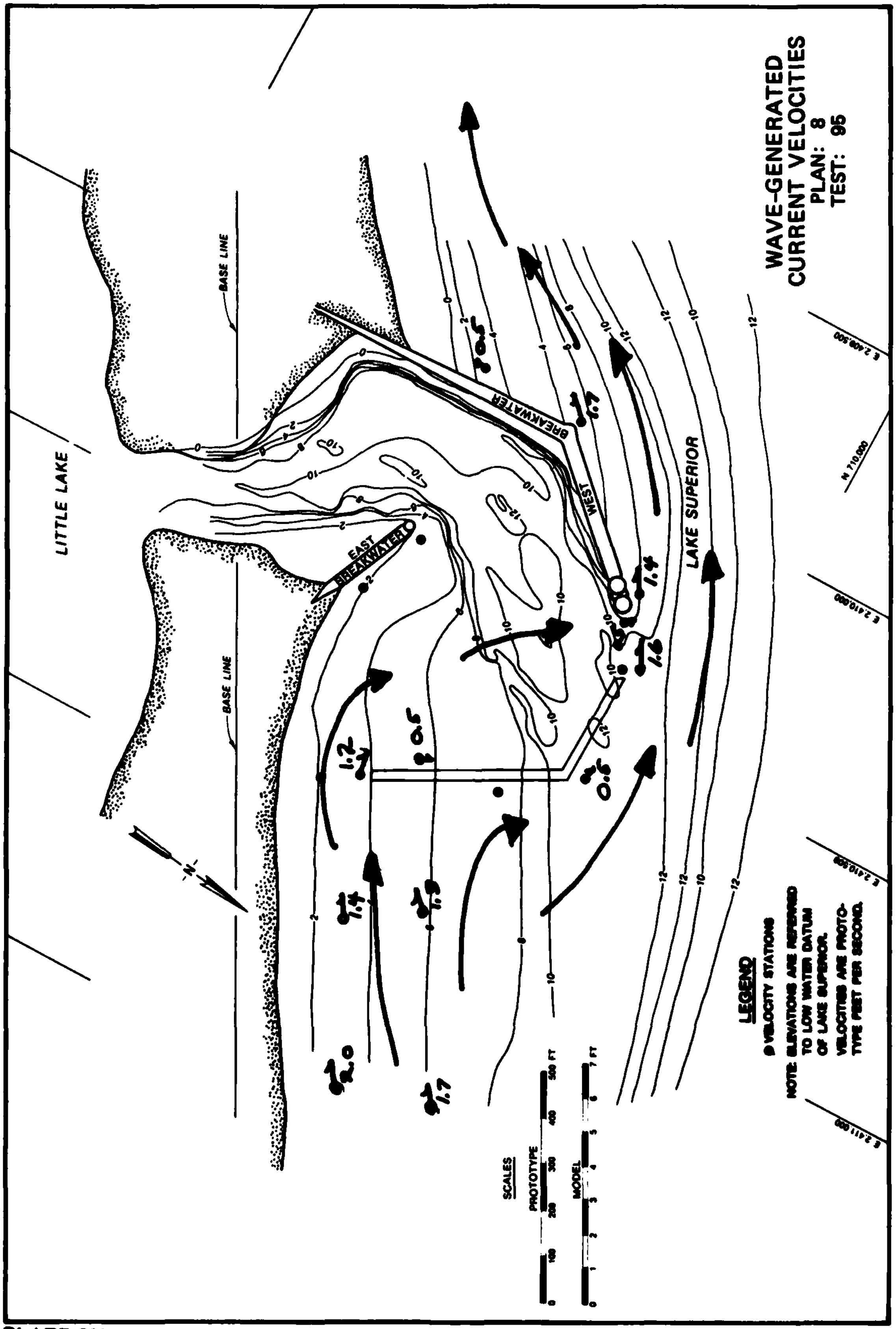
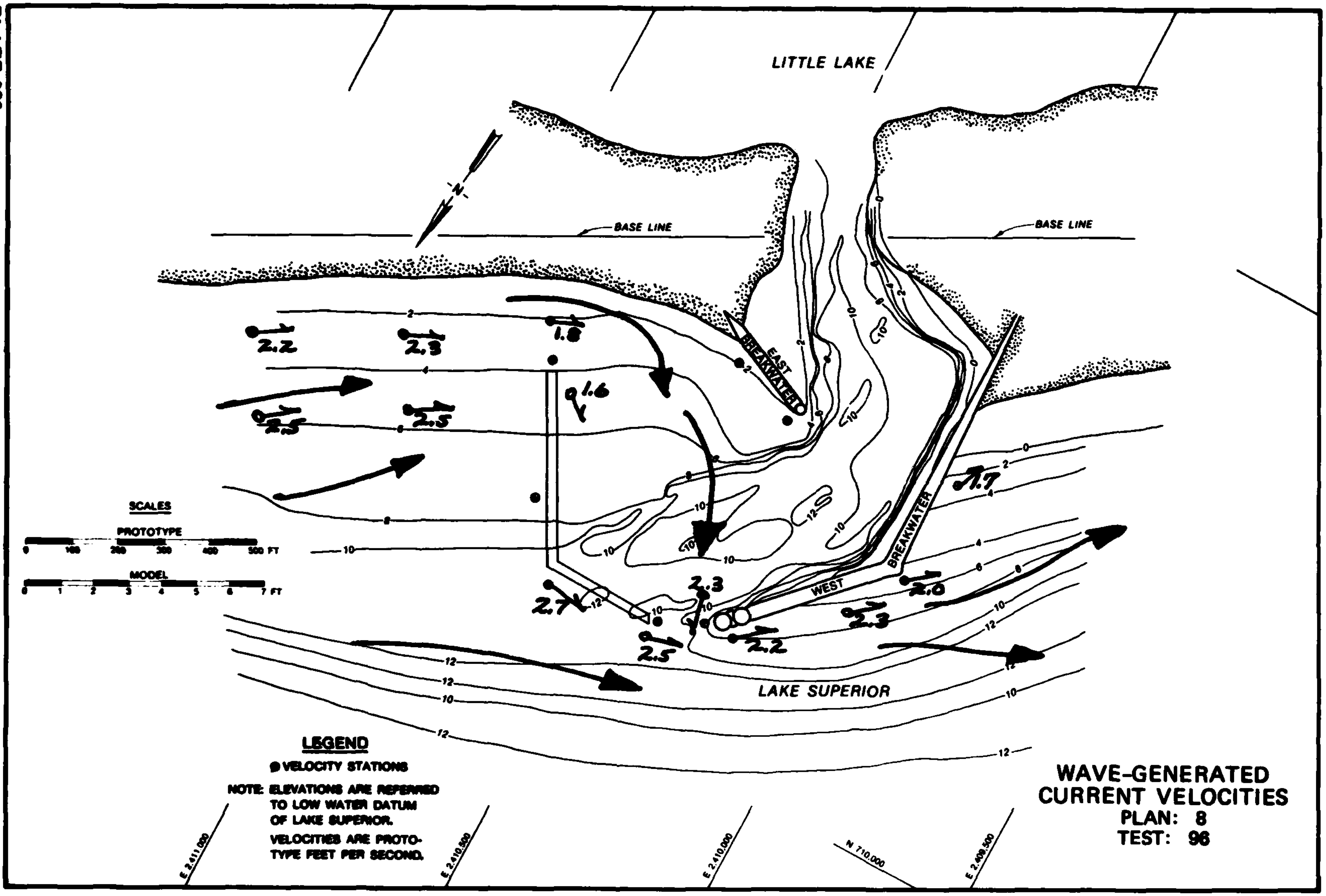

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8
TEST: 95
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
N 710,000
E 2,409,500
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 218

CONDITION Plan 8
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST **96**

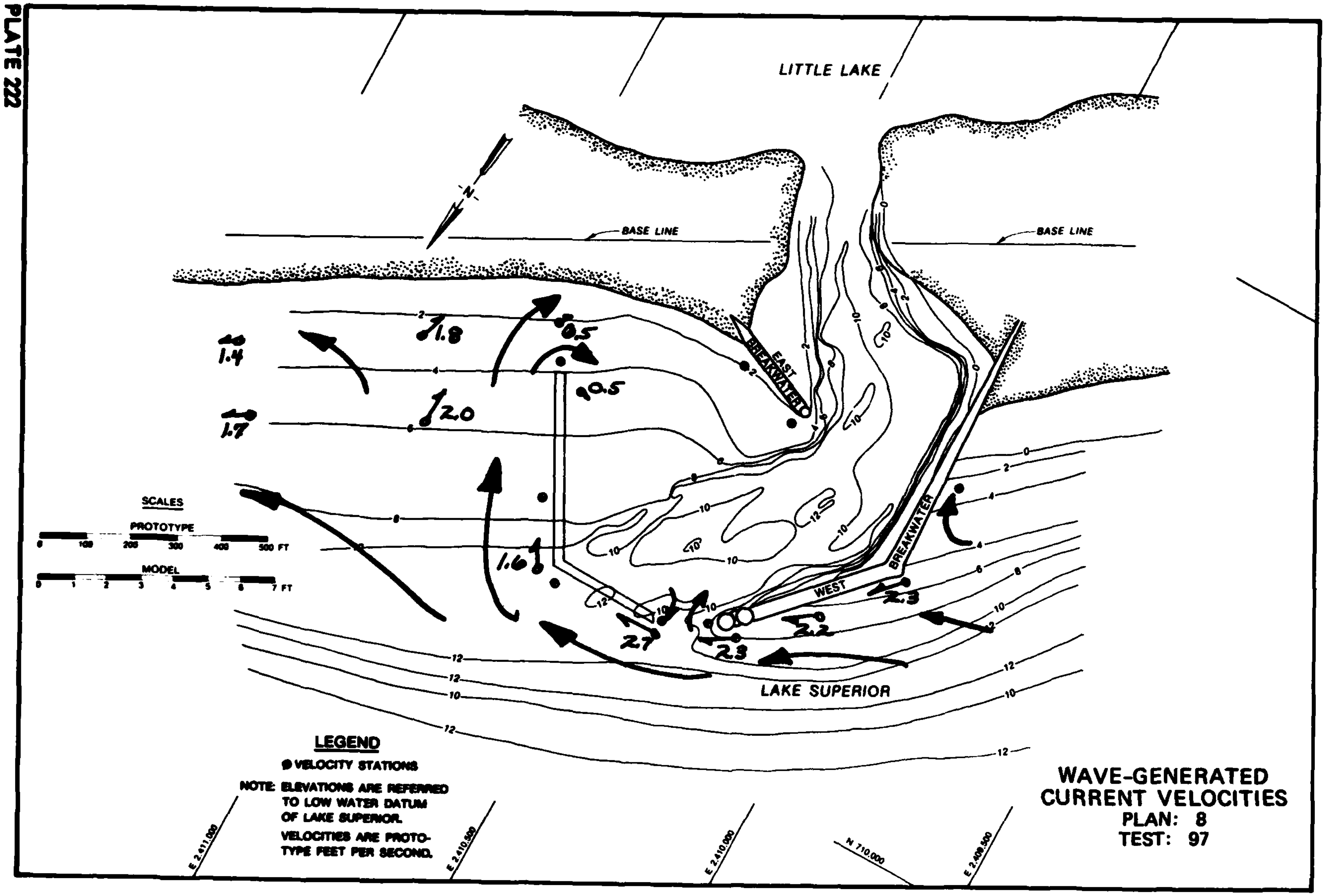


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8
TEST: 96

PLATE 220

CONDITION Plan 8
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 97

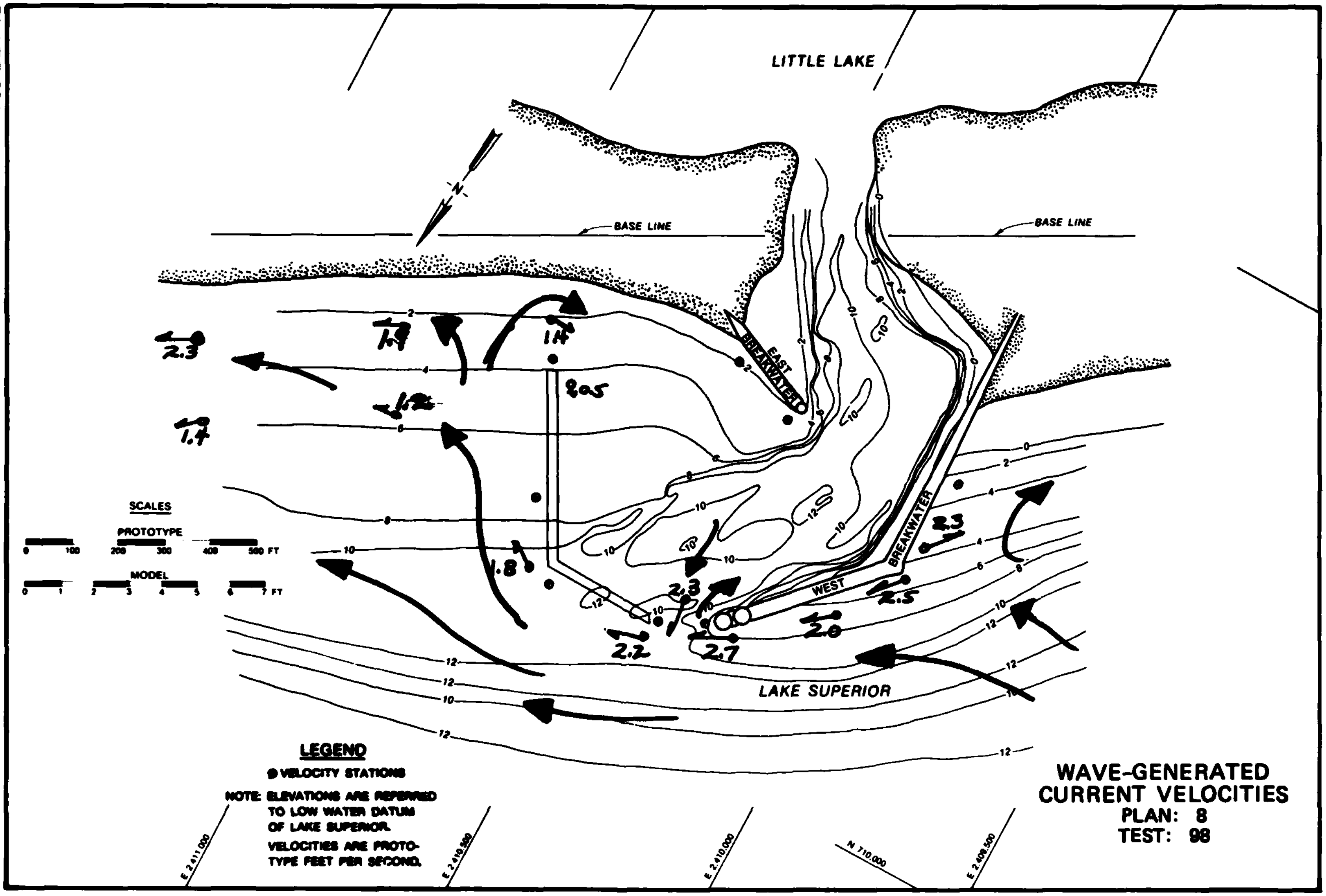


WAVE-GENERATED CURRENT VELOCITIES
PLAN: 8
TEST: 97

PLATE 222

CONDITION Plan 8
WAVE DIRECTION 304°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST **98**



WAVE-GENERATED CURRENT VELOCITIES
PLAN: 8
TEST: 98

PLATE 224

CONDITION Plan 8
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0.0

SHOALING TEST **99**

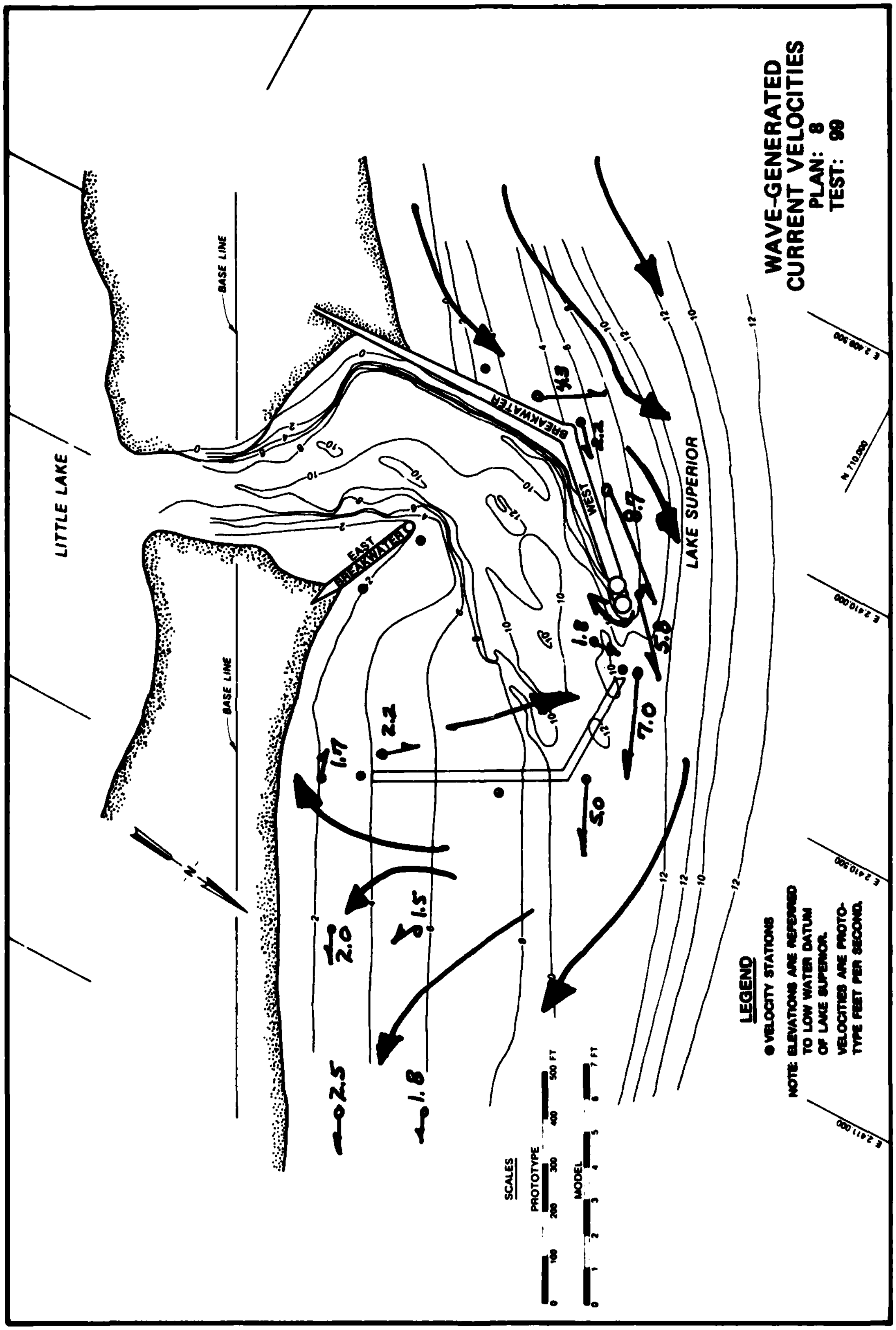
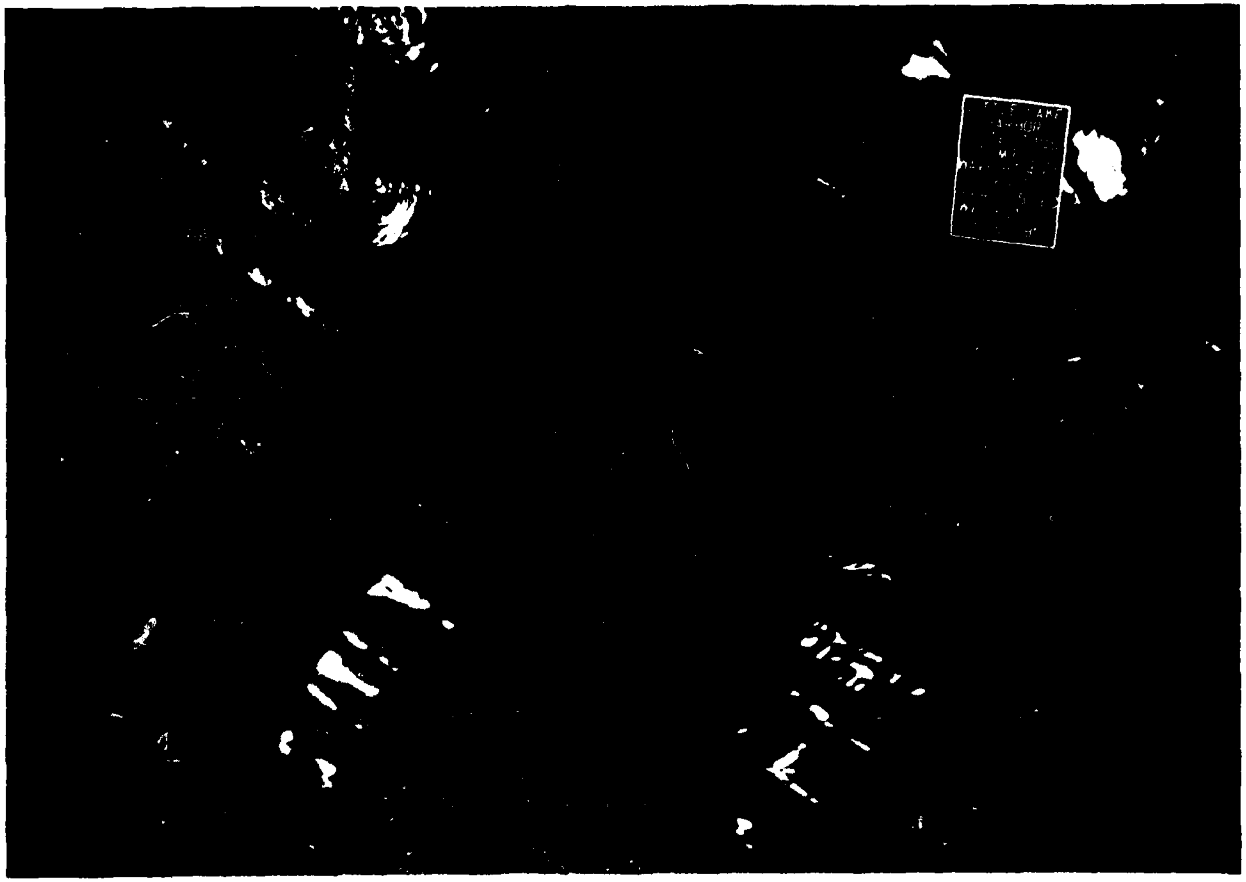
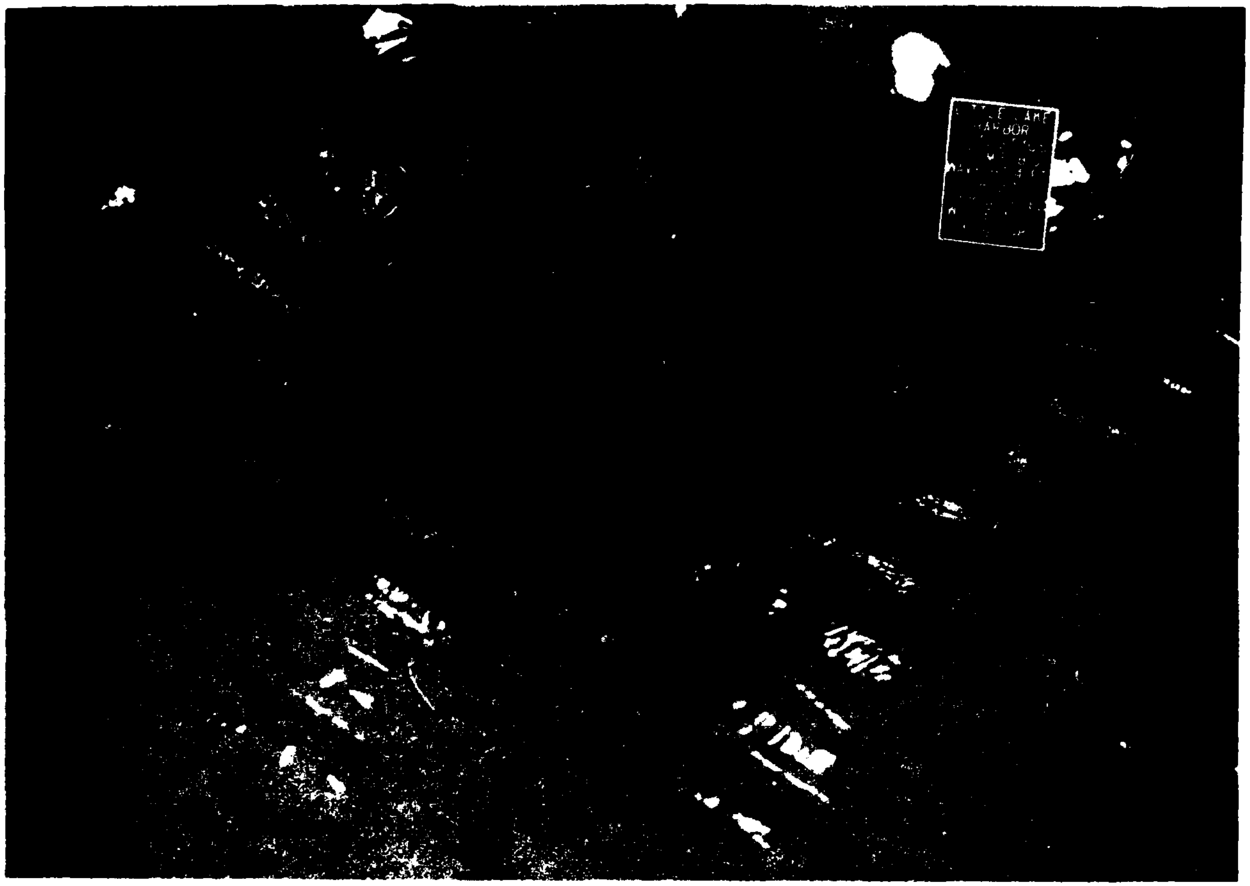

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8
TEST: 99
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
MODEL

PLATE 226



CONDITION Plan 9
WAVE DIRECTION 27
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0.0

SHOALING TEST **105A**



CONDITION Plan 9
WAVE DIRECTION 27
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0.0

SHOALING TEST 105

CONDITION Plan 10
WAVE DIRECTION 27
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 107

CONDITION Plan 8A
WAVE DIRECTION 27
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

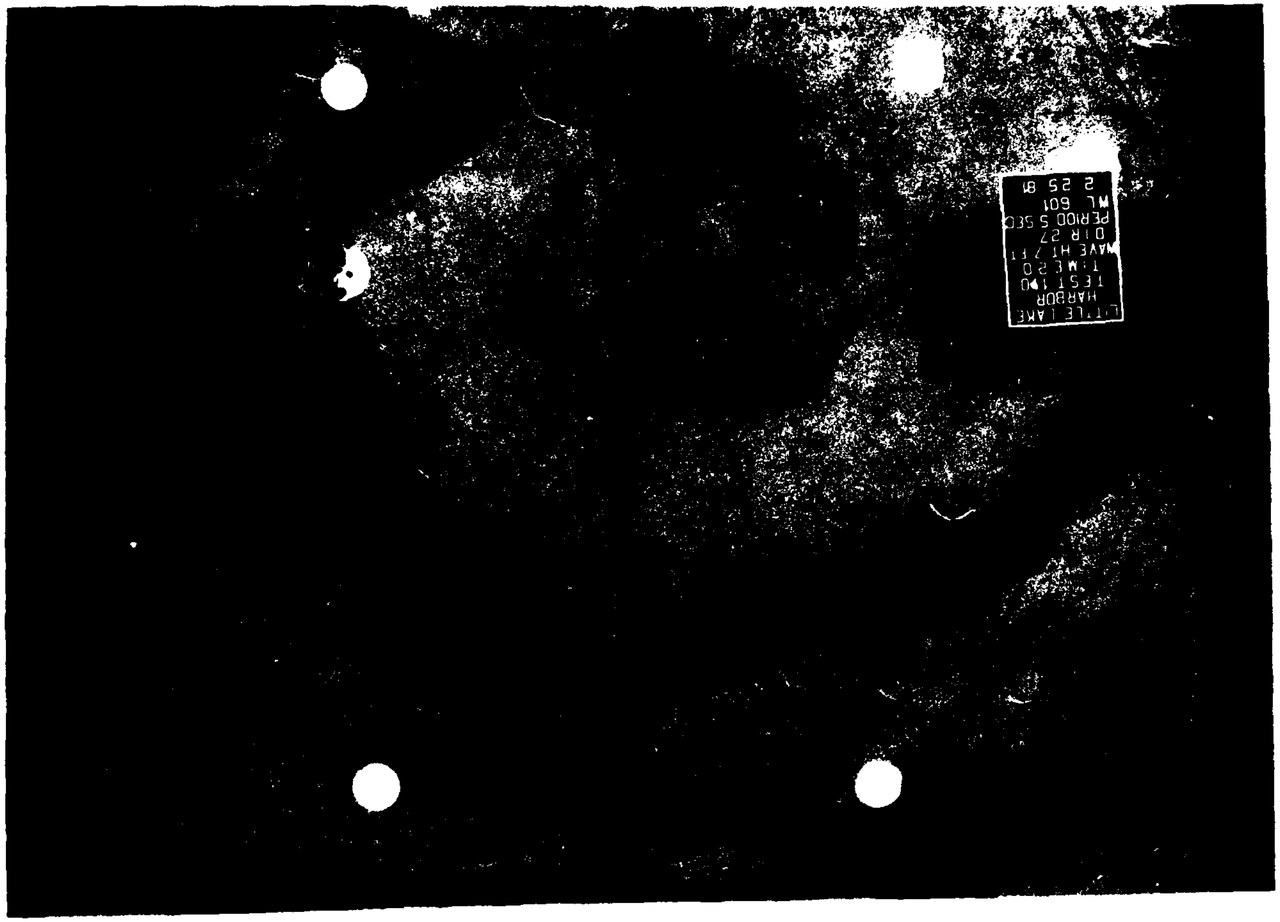
SHOALING TEST 106

CONDITION Plan 8A
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 108

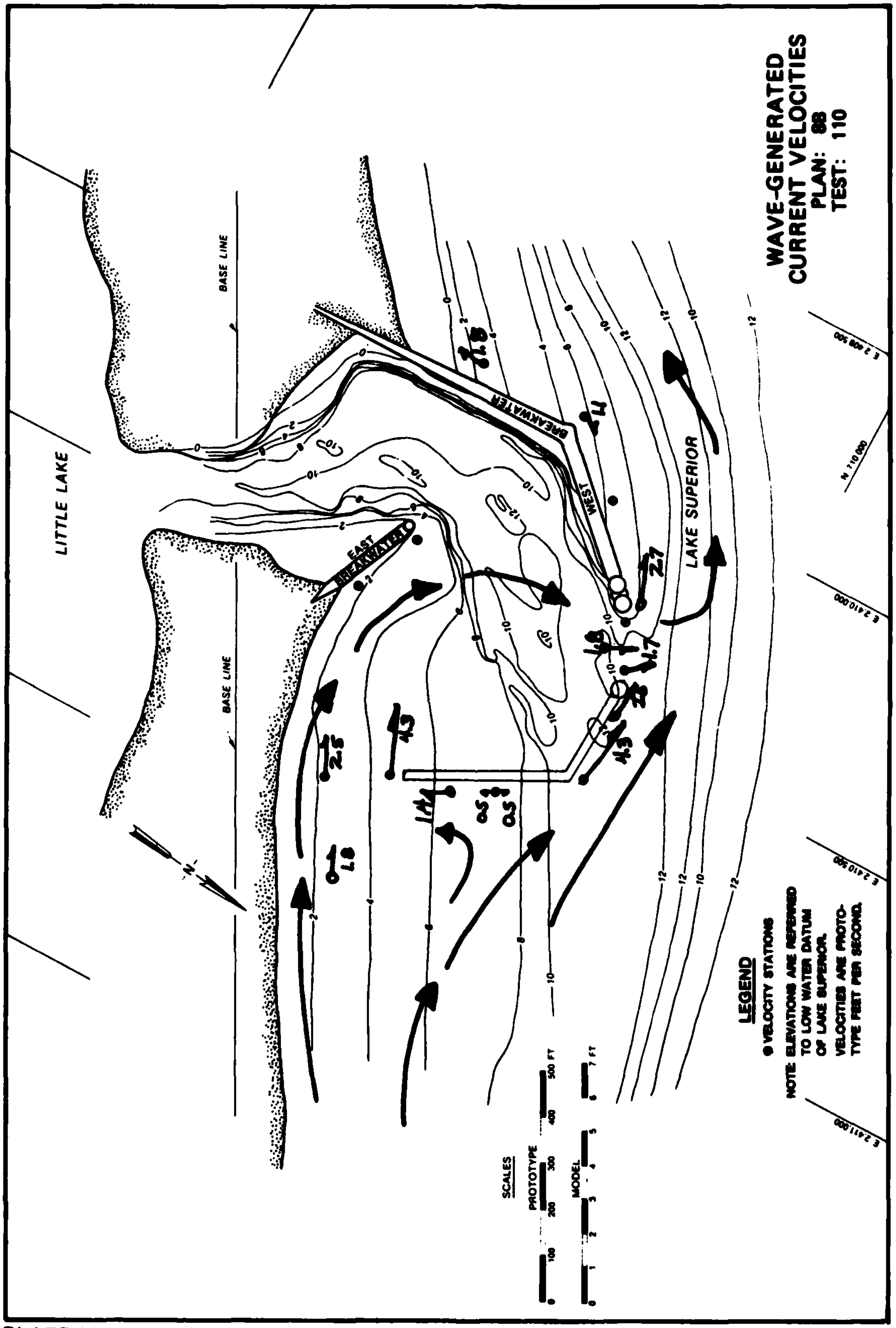
CONDITION Plan 8A
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 109



CONDITION Plan 8B
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 110


WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 88
TEST: 110
LITTLE LAKE
LAKE SUPERIOR
WEST BREAKWATER
EAST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
E 2 409 500
N 110 000
E 2 410 000
E 2 410 500
E 2 411 000

CONDITION Plan 8B
WAVE DIRECTION 27°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST 112

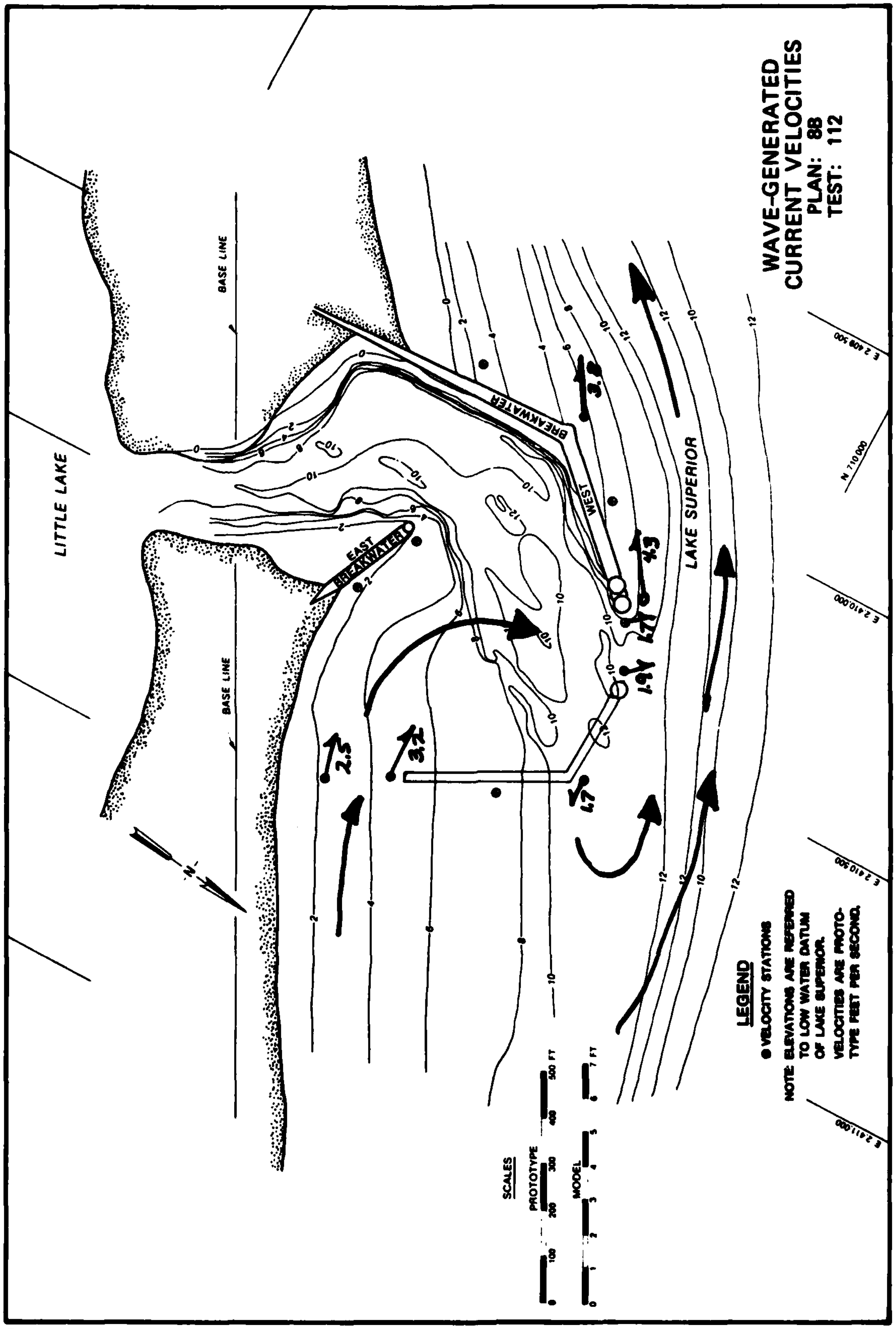

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 88
TEST: 112
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N 710,000
E 2,409,500
E 2,410,000
E 2,410,500
E 2,411,000
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 236

CONDITION Plan 8B
WAVE DIRECTION 40°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 114

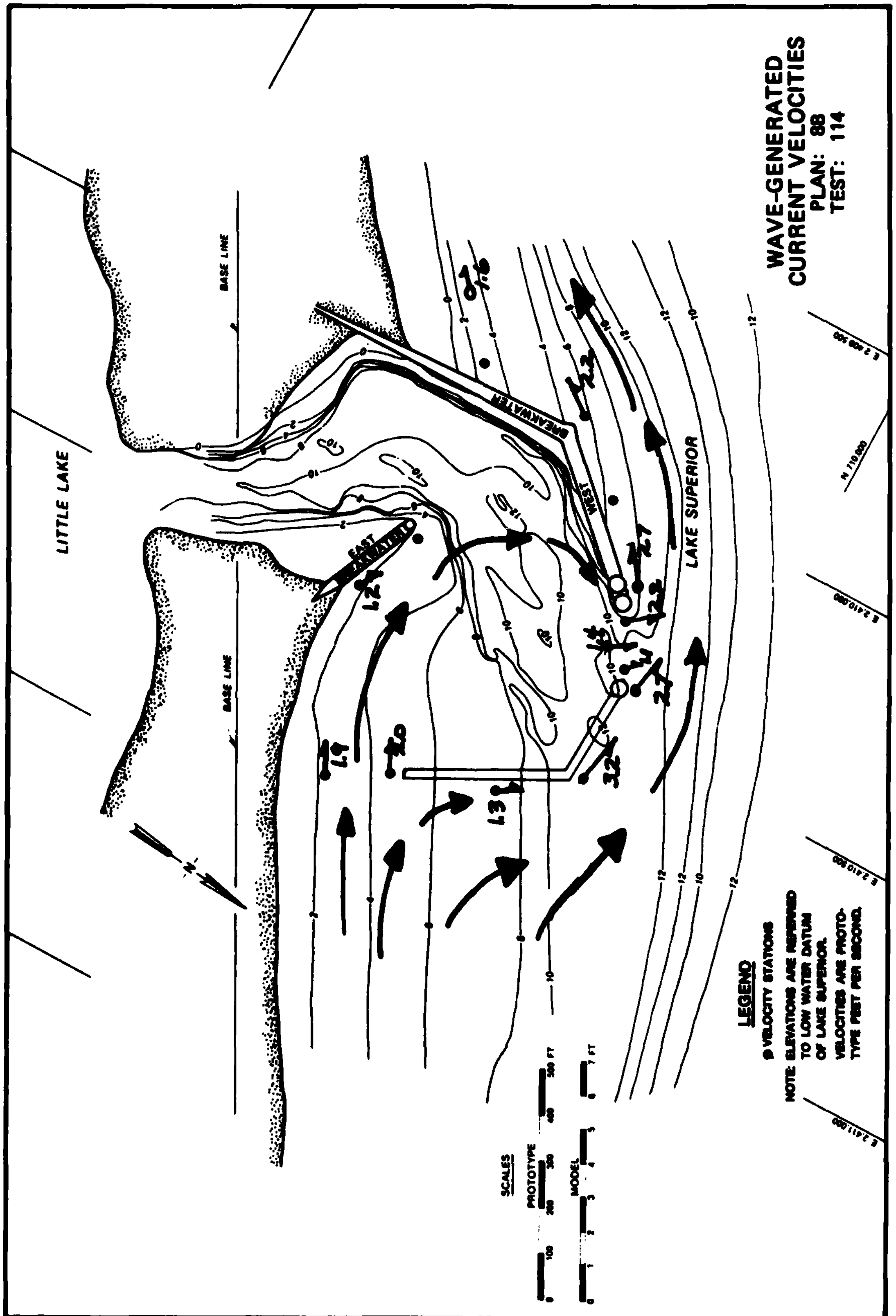

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 88
TEST: 114
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 238

CONDITION Plan 8B
WAVE DIRECTION 40°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST 115

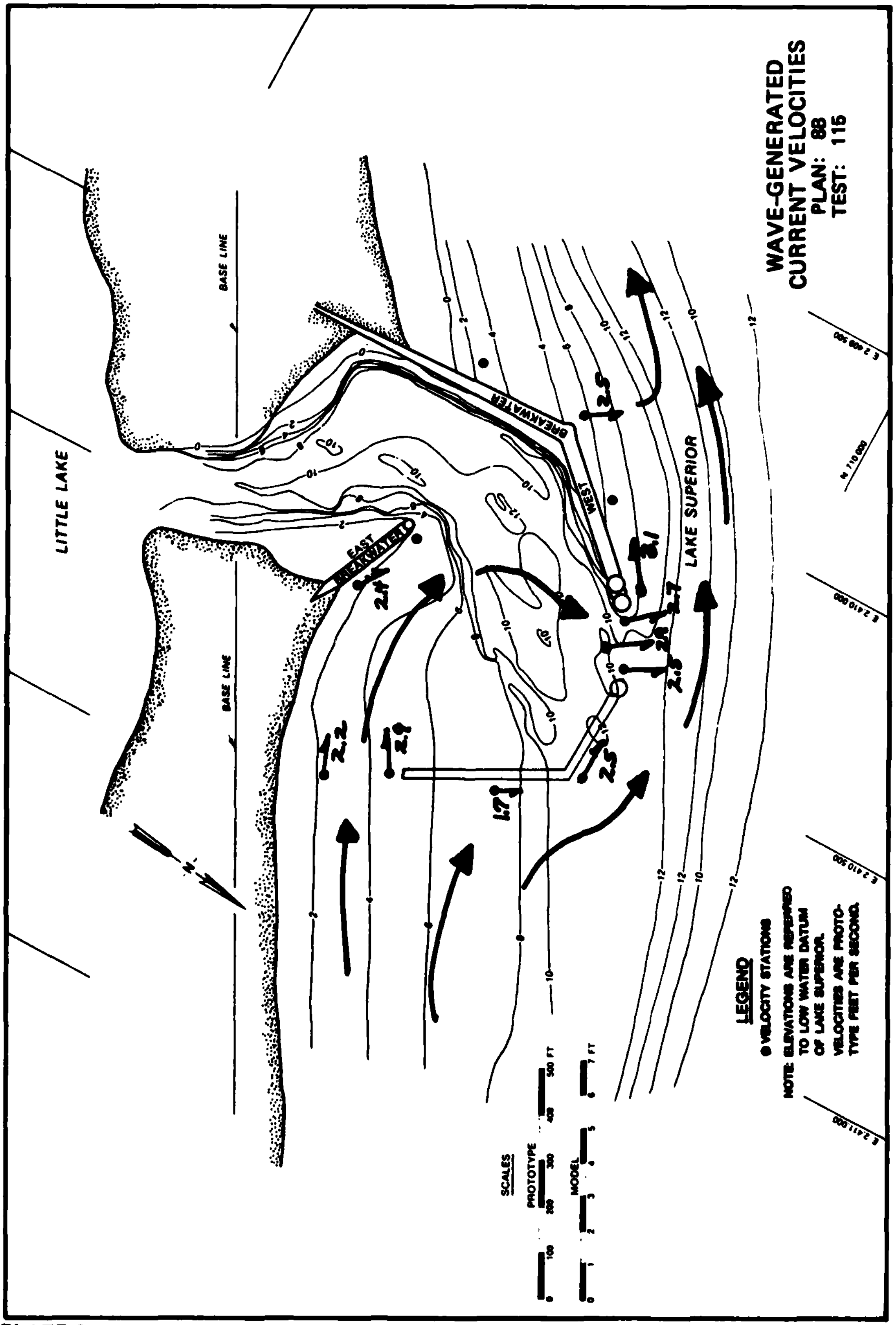
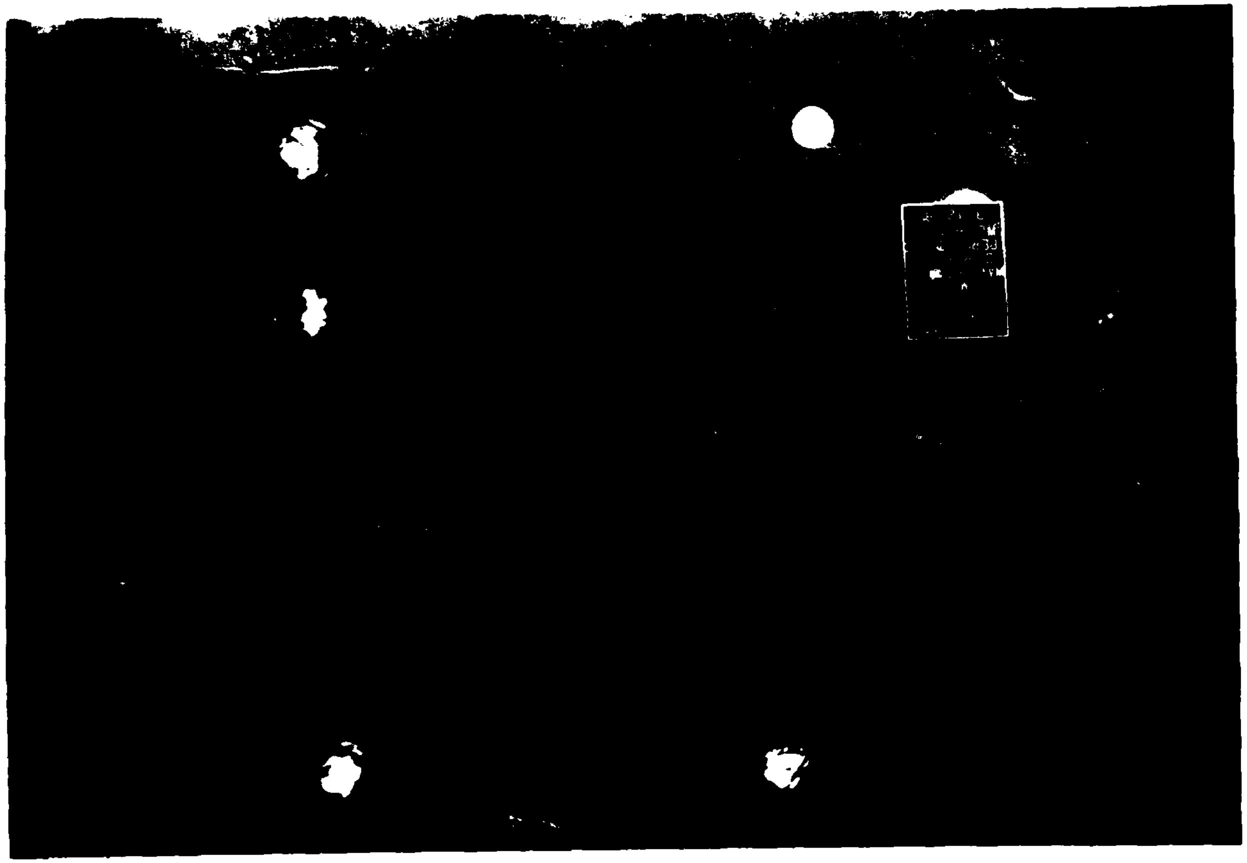
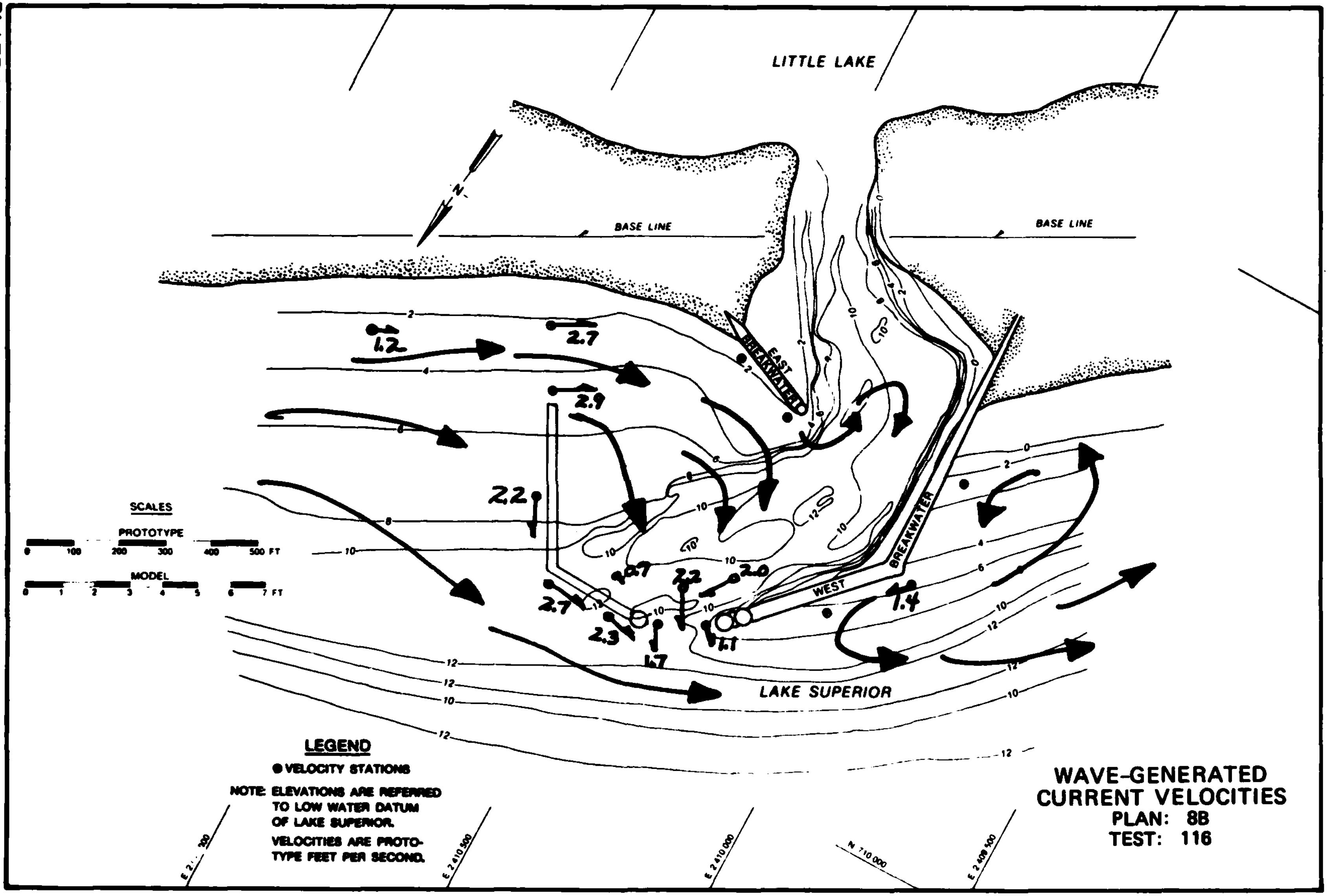

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8B
TEST: 115
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
N
LEGEND
● VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
N 710 000
E 2 409 500
E 2 410 000
E 2 410 500
E 2 411 000
2.5
2.1
2.7
2.6
2.8
2.4
2.2
2.9
2.5
1.7

PLATE 240



CONDITION Plan 8B
WAVE DIRECTION 359°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 116

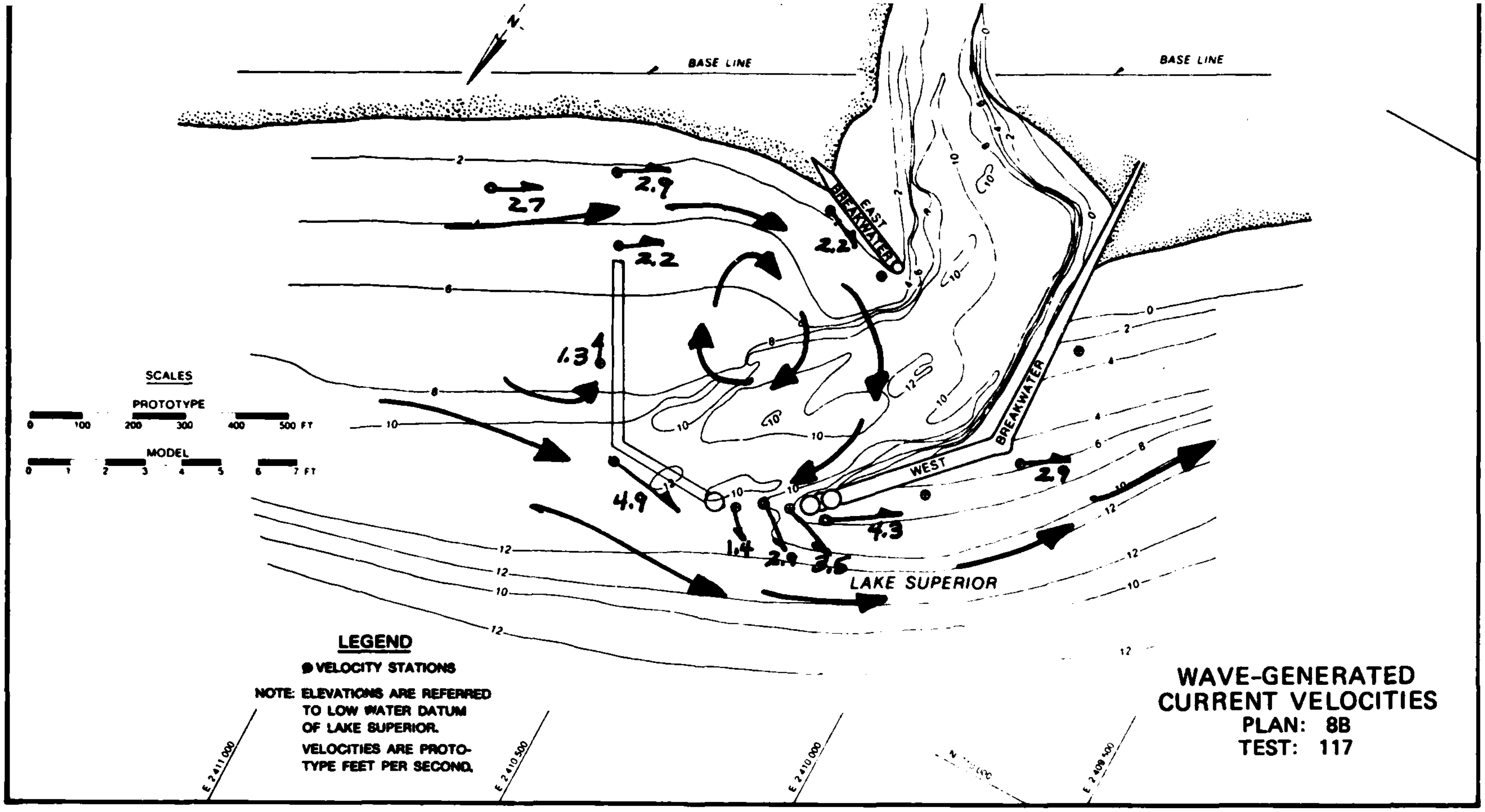


LITTLE LAKE
BASE LINE
BASE LINE
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
1.2
2.7
2.9
2.2
2.7
2.3
1.7
2.2
2.0
1.1
1.4
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8B
TEST: 116

PLATE 242

CONDITION Plan 8B
WAVE DIRECTION 359°
WAVE PERIOD 7 sec
WAVE HEIGHT 10 ft
SEICHE HEIGHT 0.0

SHOALING TEST 117



WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8B
TEST: 117

CONDITION Plan 8B
WAVE DIRECTION 304°
WAVE PERIOD 9 sec
WAVE HEIGHT 8 ft
SEICHE HEIGHT 0.0

SHOALING TEST III

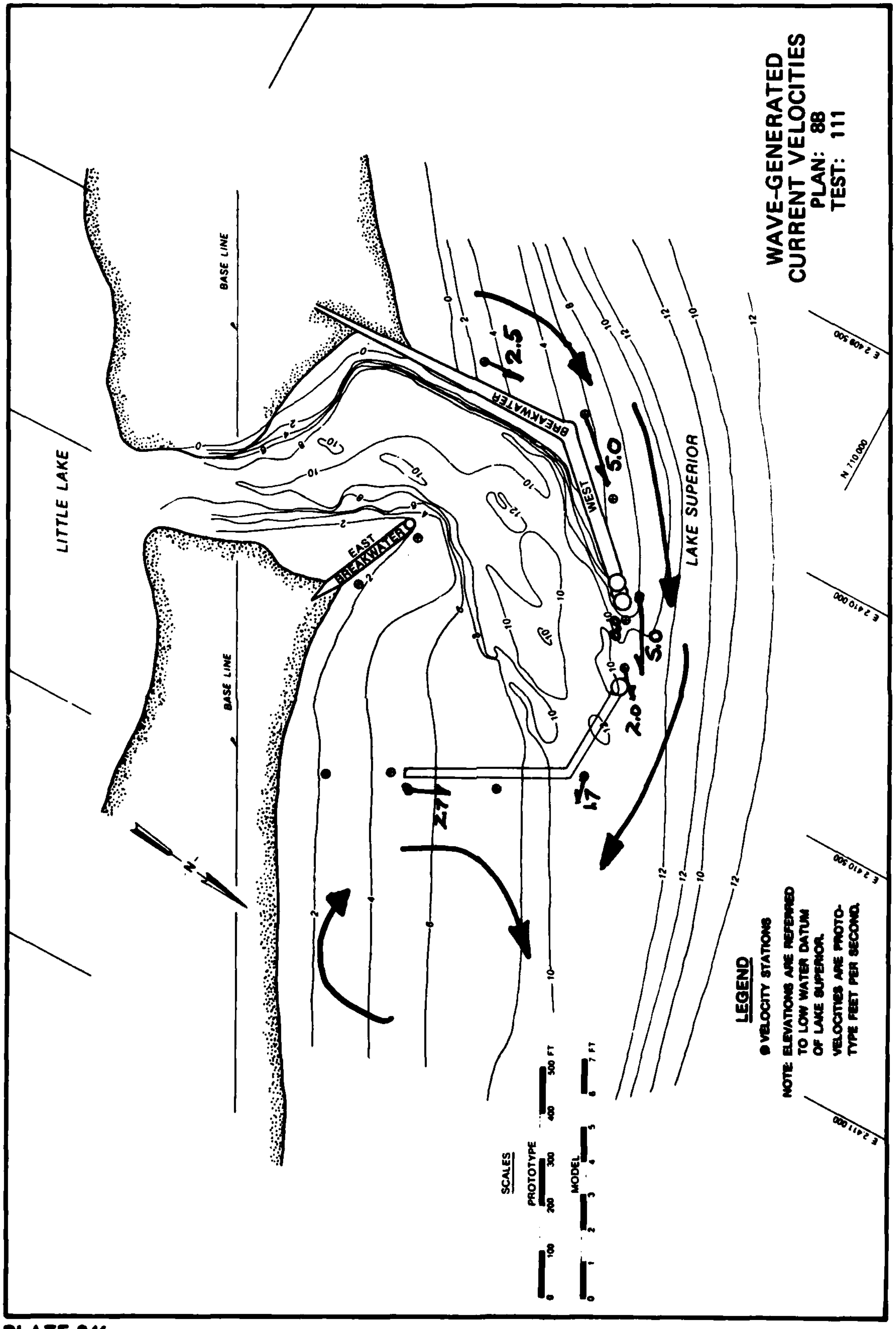
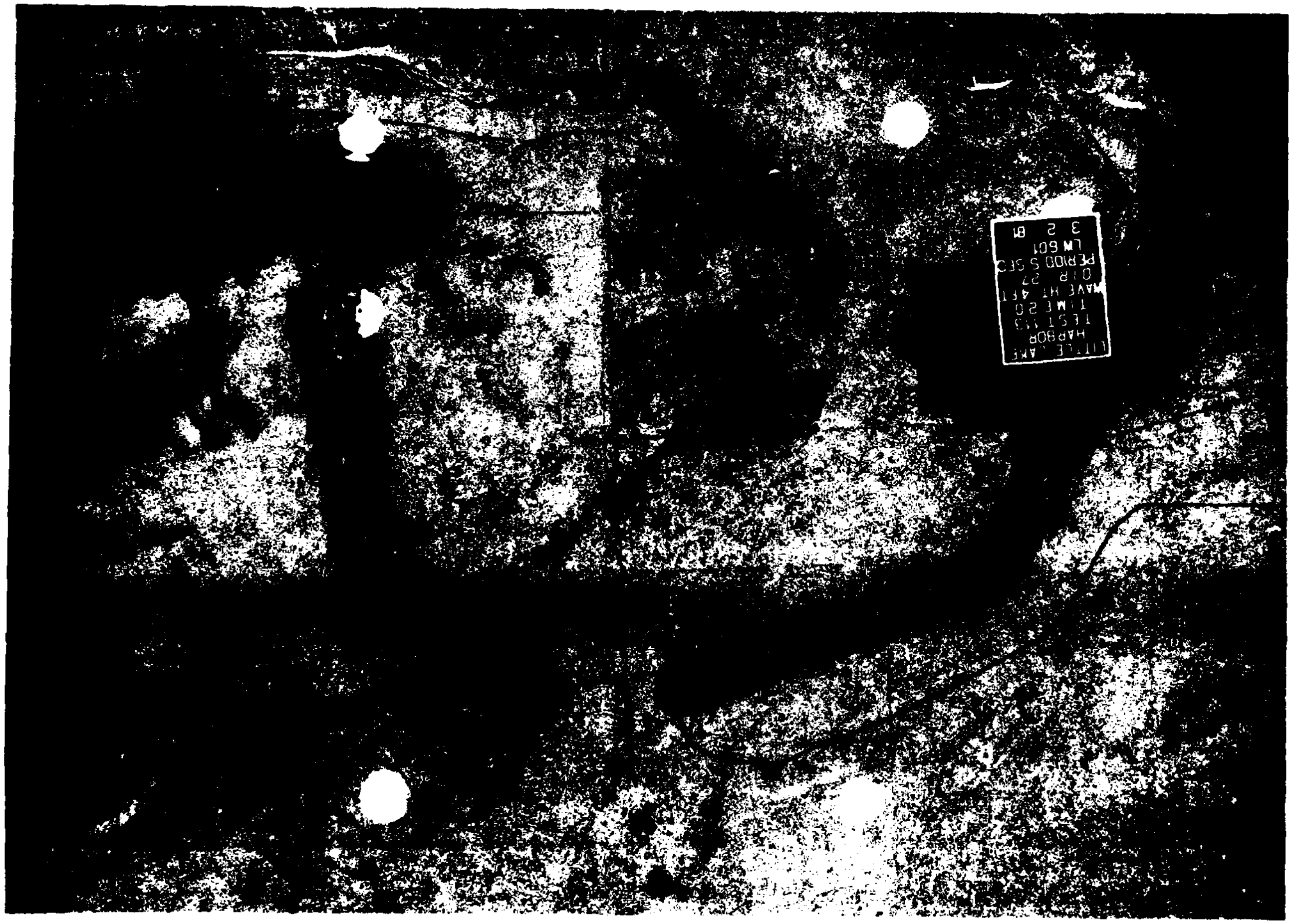
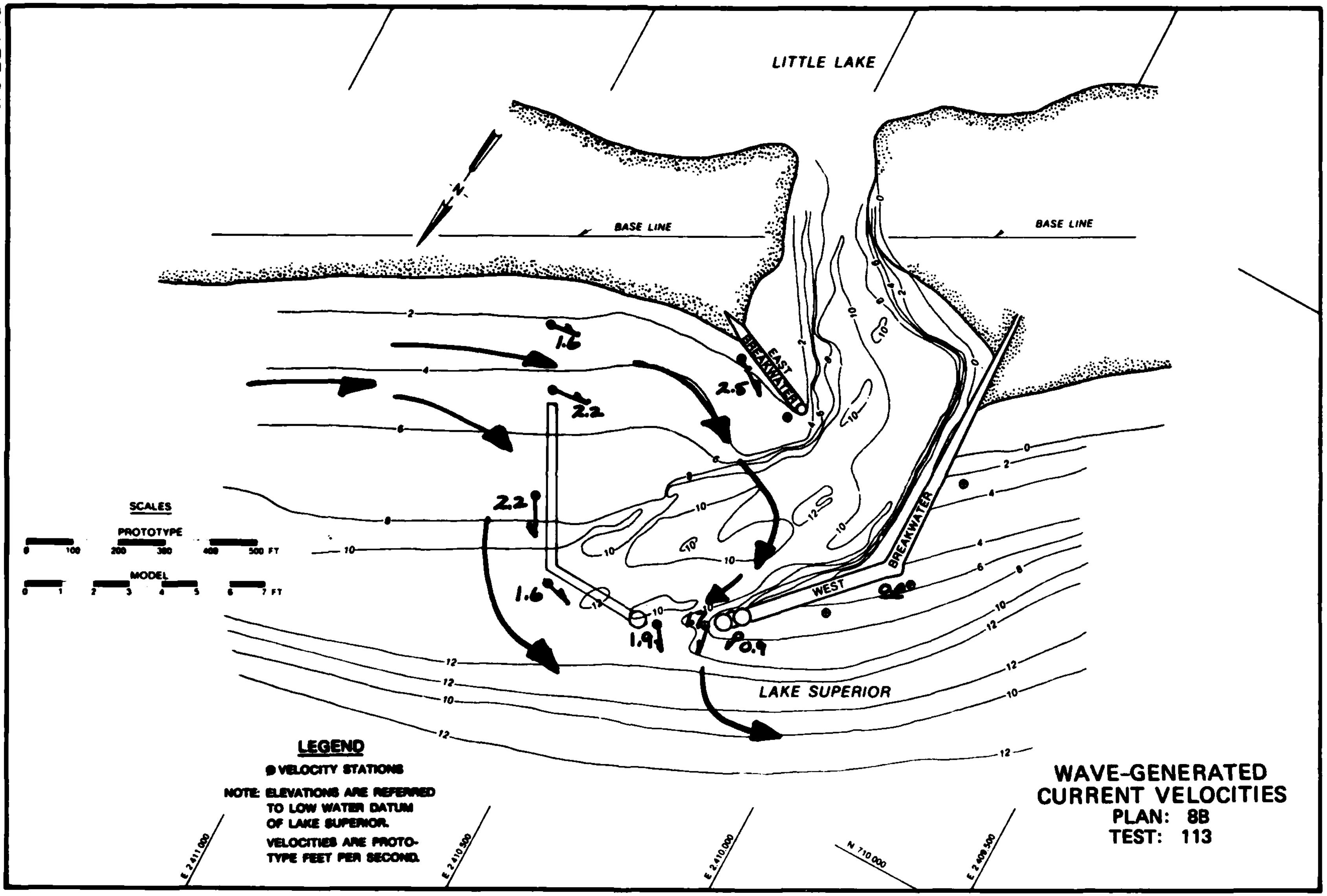

WAVE-GENERATED
CURRENT VELOCITIES
PLAN: 8B
TEST: 111
LITTLE LAKE
LAKE SUPERIOR
EAST BREAKWATER
WEST BREAKWATER
BASE LINE
BASE LINE
12.5
5.0
5.0
2.0
1.7
2.7
E 2 409 500
N 710,000
E 2 410 000
E 2 410 500
E 2 411 000
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT

PLATE 246



CONDITION Plan 8B
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0.0

SHOALING TEST 113 (2HRS)



LITTLE LAKE
BASE LINE
BASE LINE
N
EAST BREAKWATER
WEST BREAKWATER
LAKE SUPERIOR
1.6
2.2
2.5
2.2
1.6
1.9
0.9
SCALES
PROTOTYPE
0 100 200 300 400 500 FT
MODEL
0 1 2 3 4 5 6 7 FT
LEGEND
VELOCITY STATIONS
NOTE: ELEVATIONS ARE REFERRED TO LOW WATER DATUM OF LAKE SUPERIOR.
VELOCITIES ARE PROTOTYPE FEET PER SECOND.
E 2,411,000
E 2,410,500
E 2,410,000
N 710,000
E 2,409,500
WAVE-GENERATED CURRENT VELOCITIES
PLAN: 8B
TEST: 113

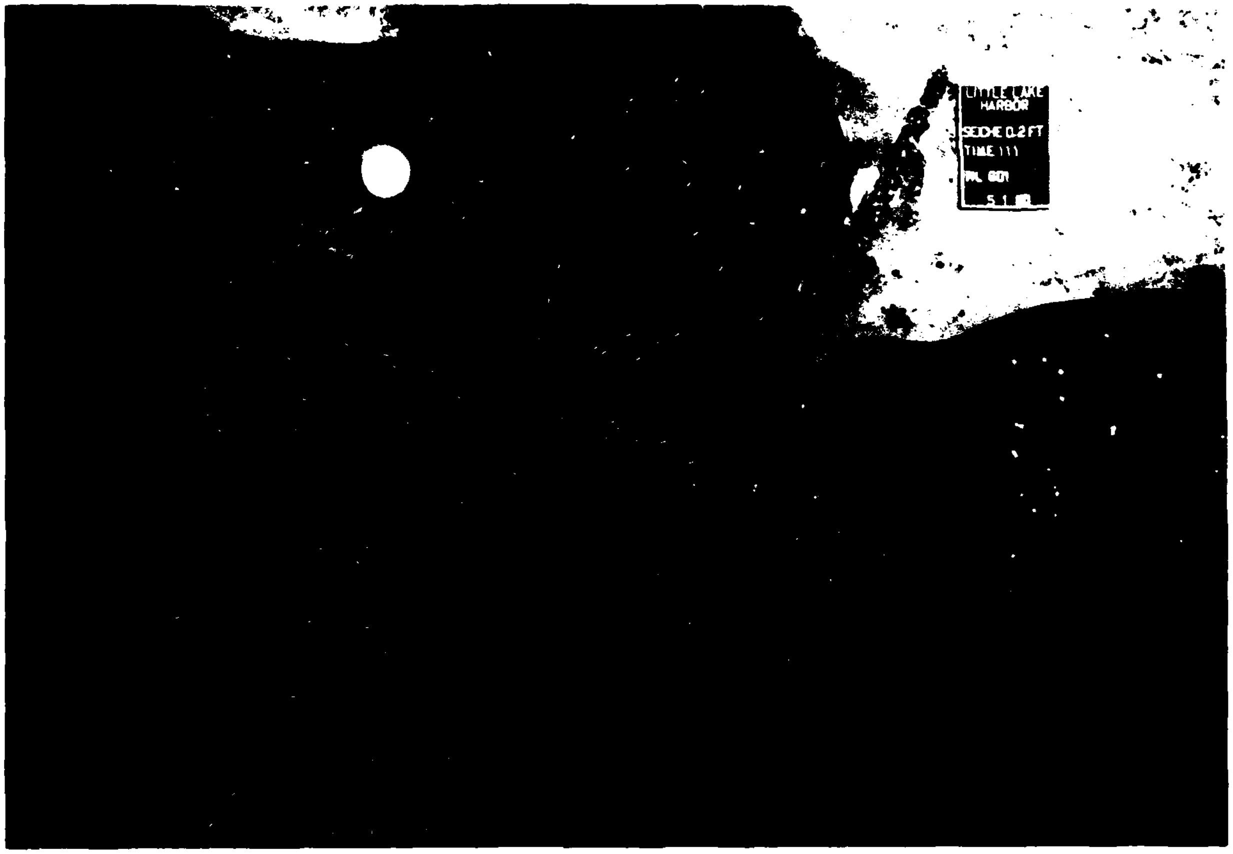
PLATE 248

CONDITION Plan 8B
WAVE DIRECTION 27°
WAVE PERIOD 5 sec
WAVE HEIGHT 4 ft
SEICHE HEIGHT 0.0

SHOALING TEST 113 (10 HRS)

CONDITION Plan 8B
WAVE DIRECTION 304°
WAVE PERIOD 5 sec
WAVE HEIGHT 7 ft
SEICHE HEIGHT 0.0

SHOALING TEST 113(11HRS)



BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.2 FT

SCALES IN FEET

PROTOTPYE 0 150 300

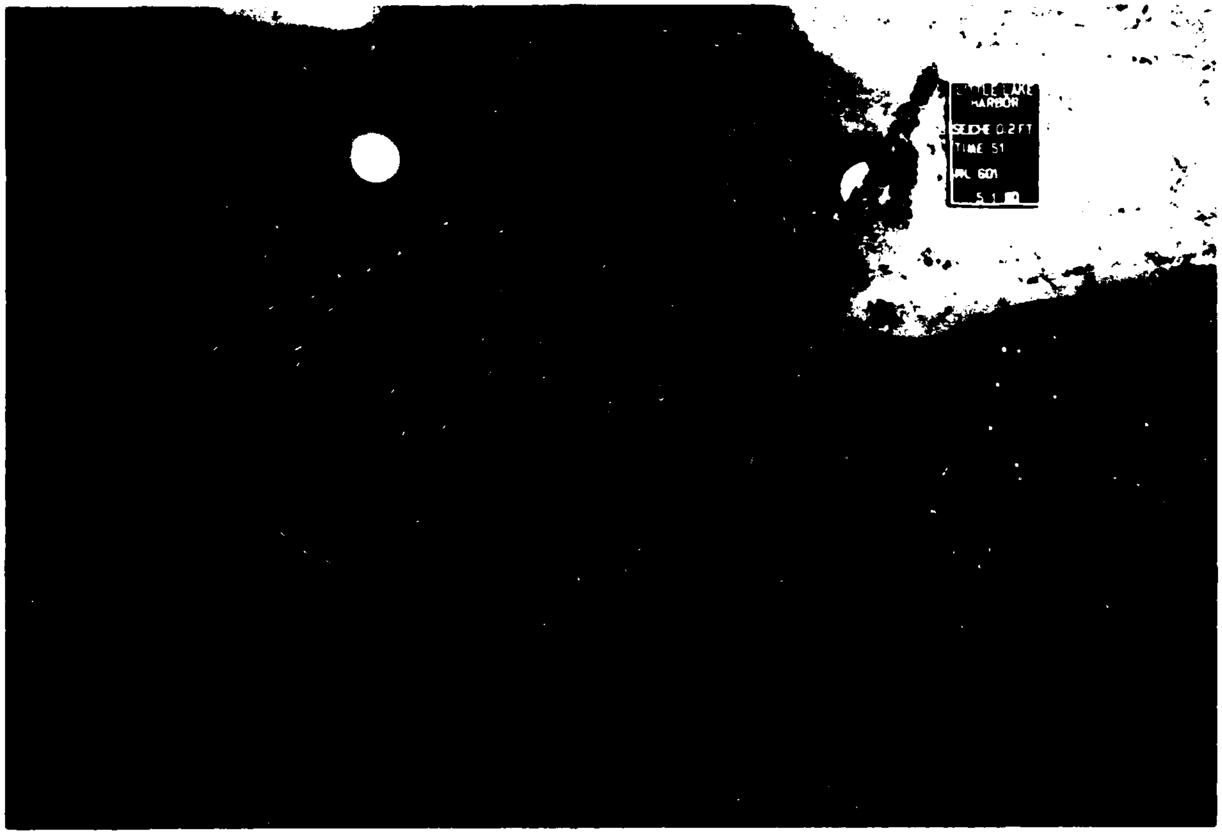
MODEL 0 2 4

VELOCITY SCALE

0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS
BASE
MAXIMUM OUTFLOW



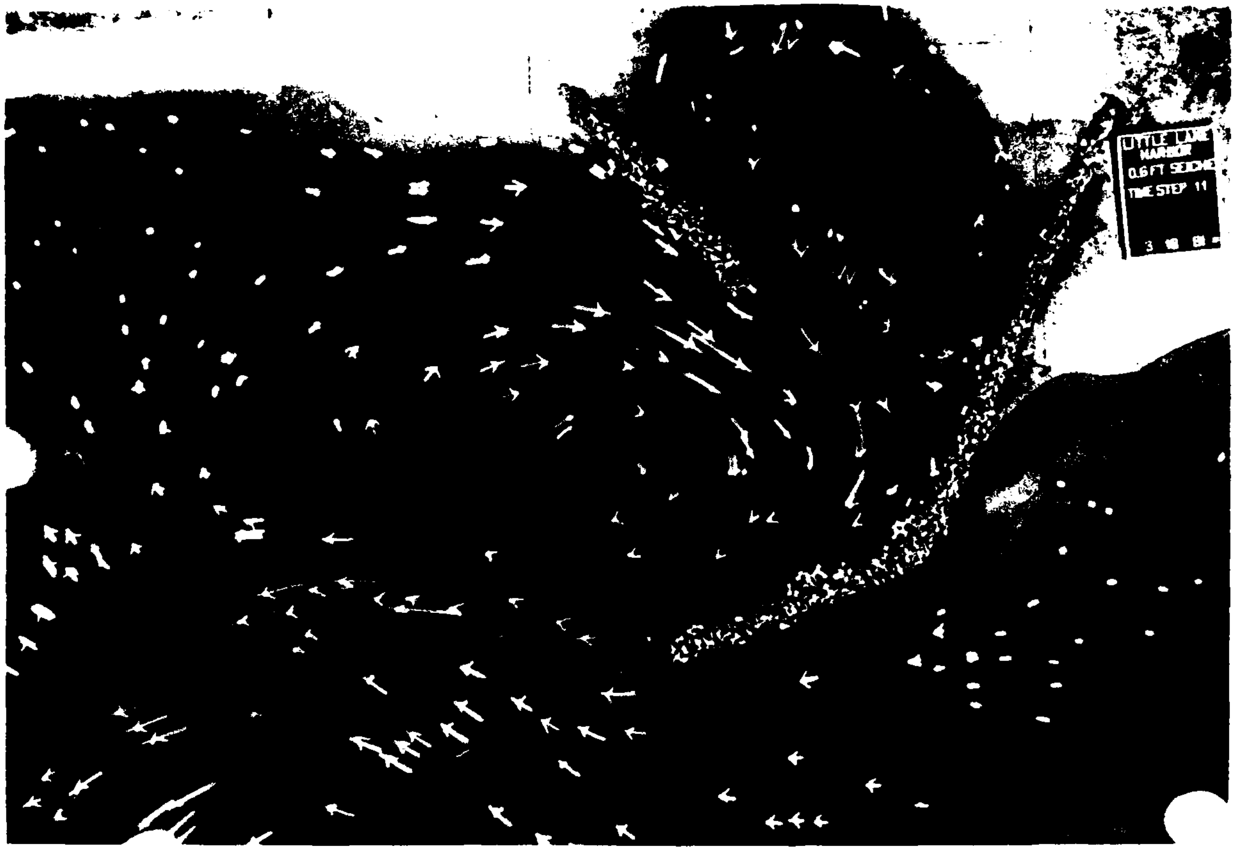
BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.2 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
BASE
MAXIMUM INFLOW

PLATE 252



BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

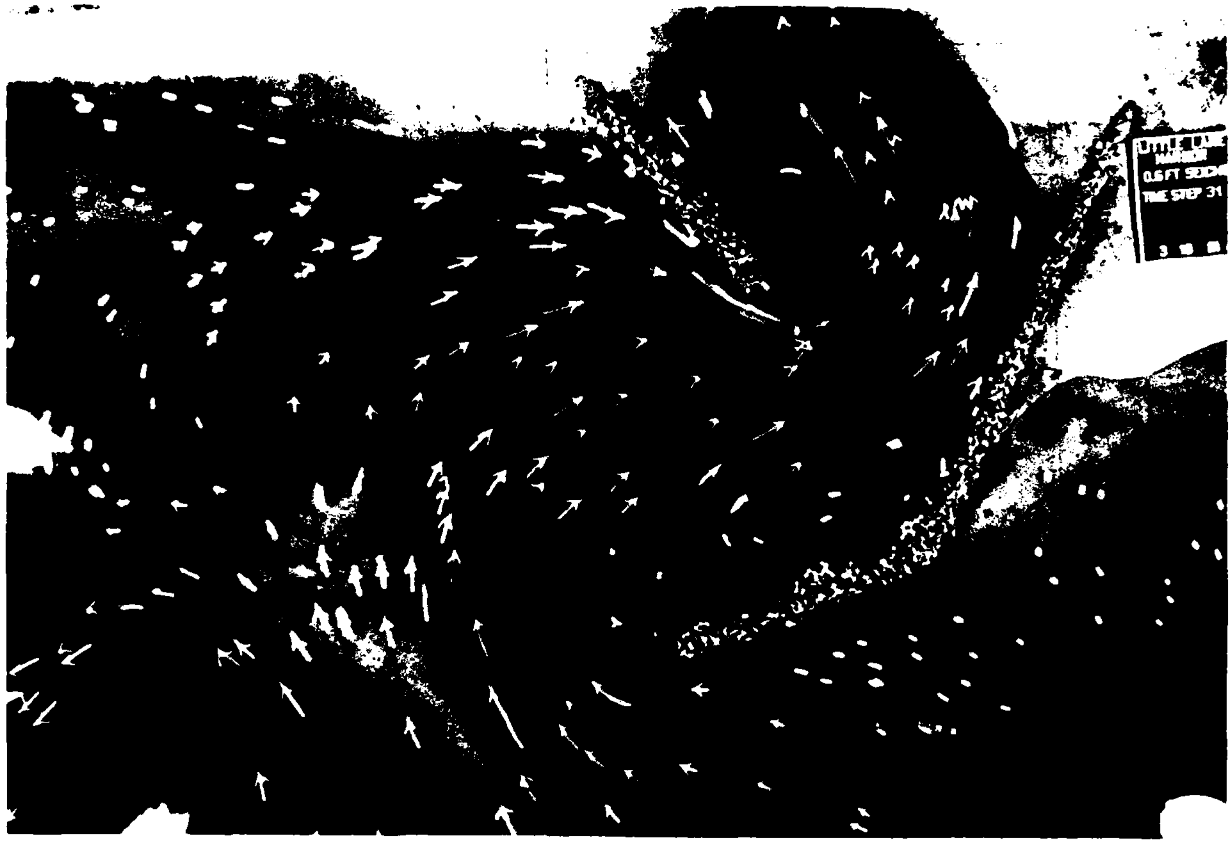
VELOCITY SCALE

0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 11

PLATE 253



BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

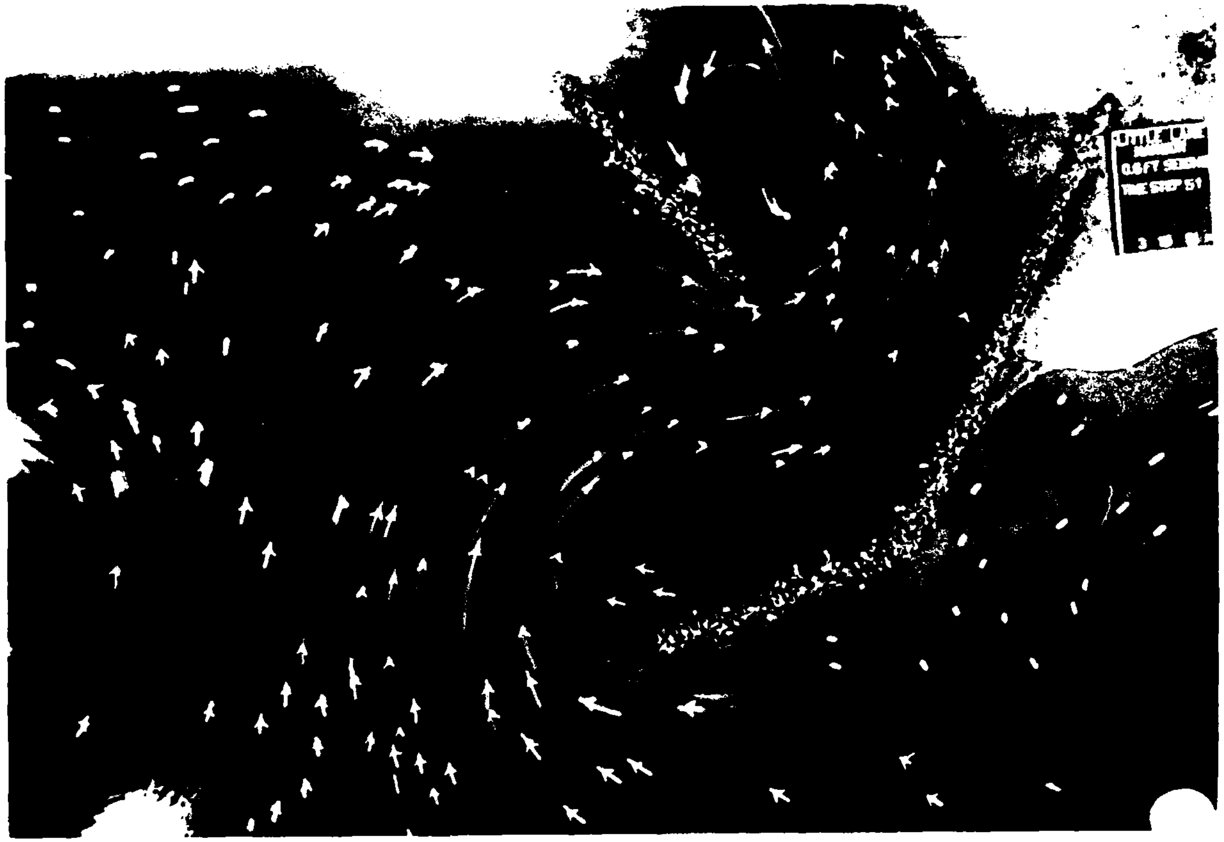
VELOCITY SCALE

0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 31

PLATE 254



BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

SURFACE CURRENTS
BASE
TIME-STEP 51

BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

VELOCITY SCALE

0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 71

BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

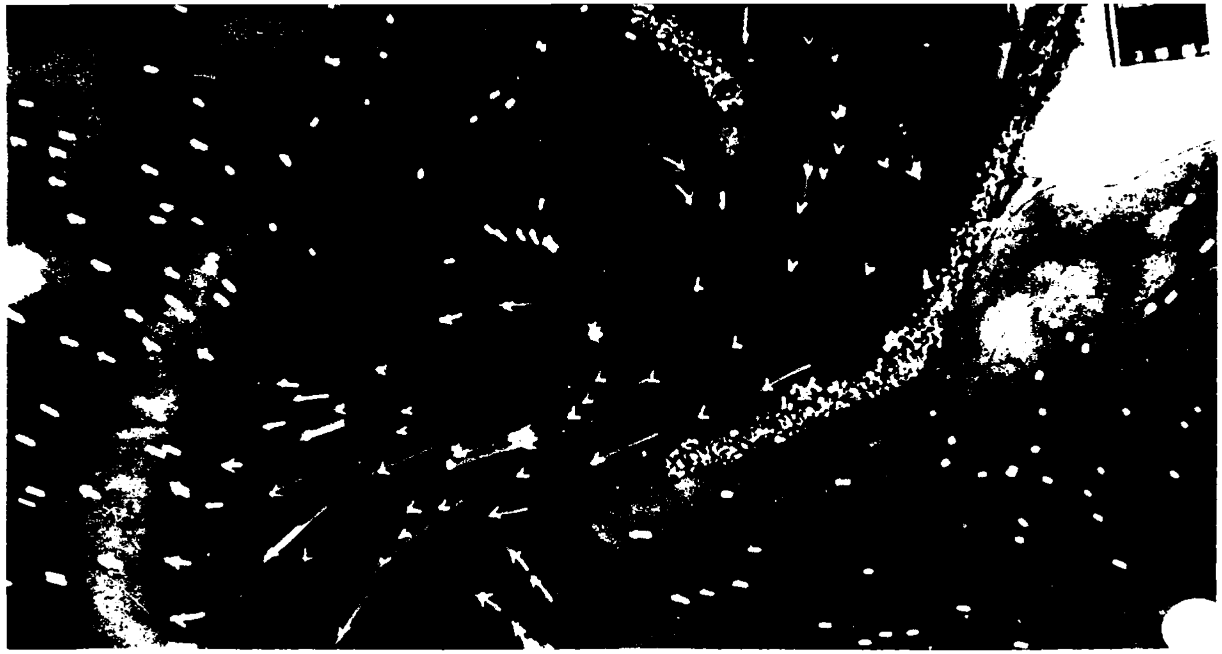
MODEL 0 2 4

VELOCITY SCALE

0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 91



BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE	0	150	300
MODEL	0	2	4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 111

BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

VELOCITY SCALE

0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 51
W/WAVES FROM 359 °

BASE = MAY 1979 SURVEY
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

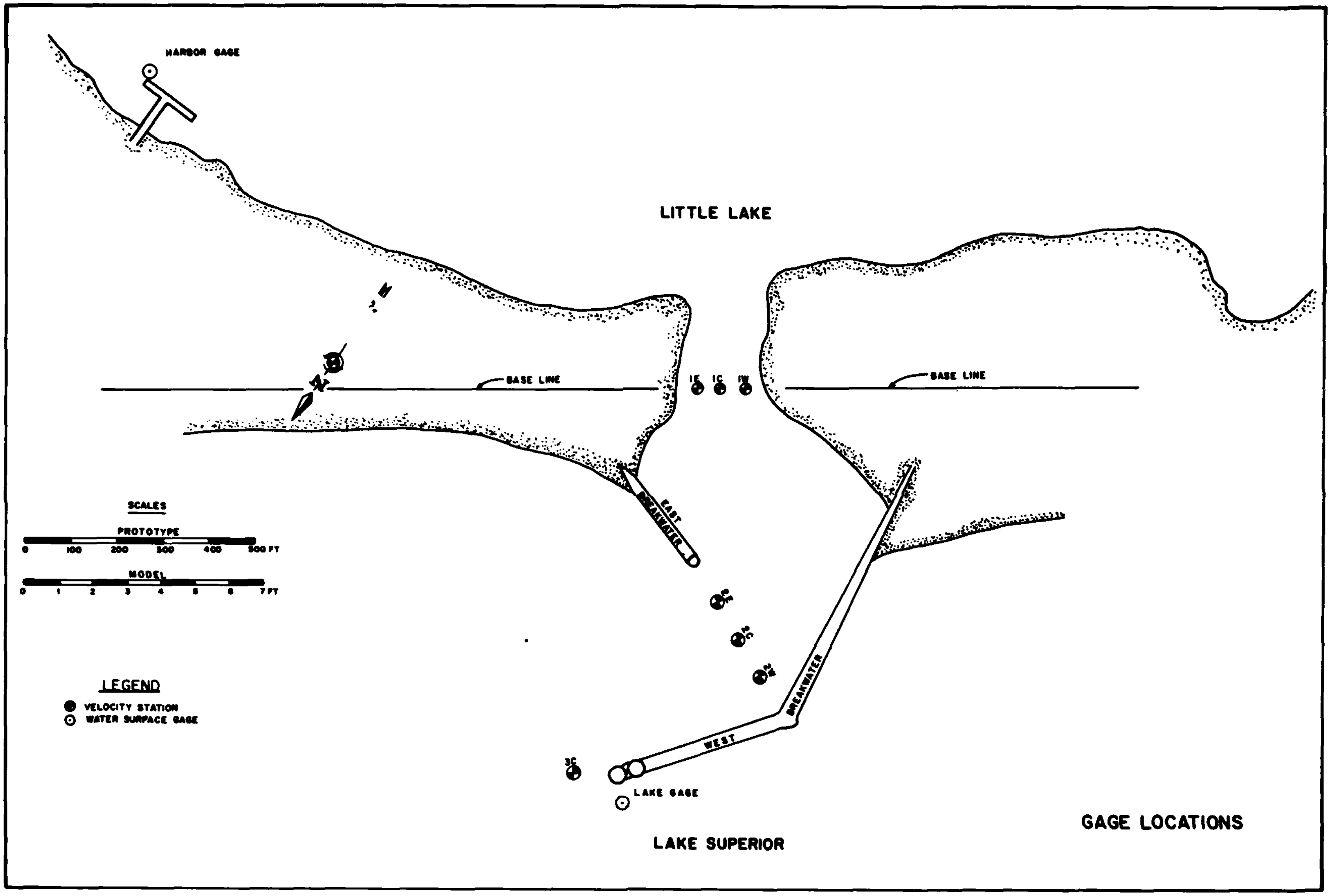
MODEL 0 2 4

VELOCITY SCALE

0 2 4 6 8

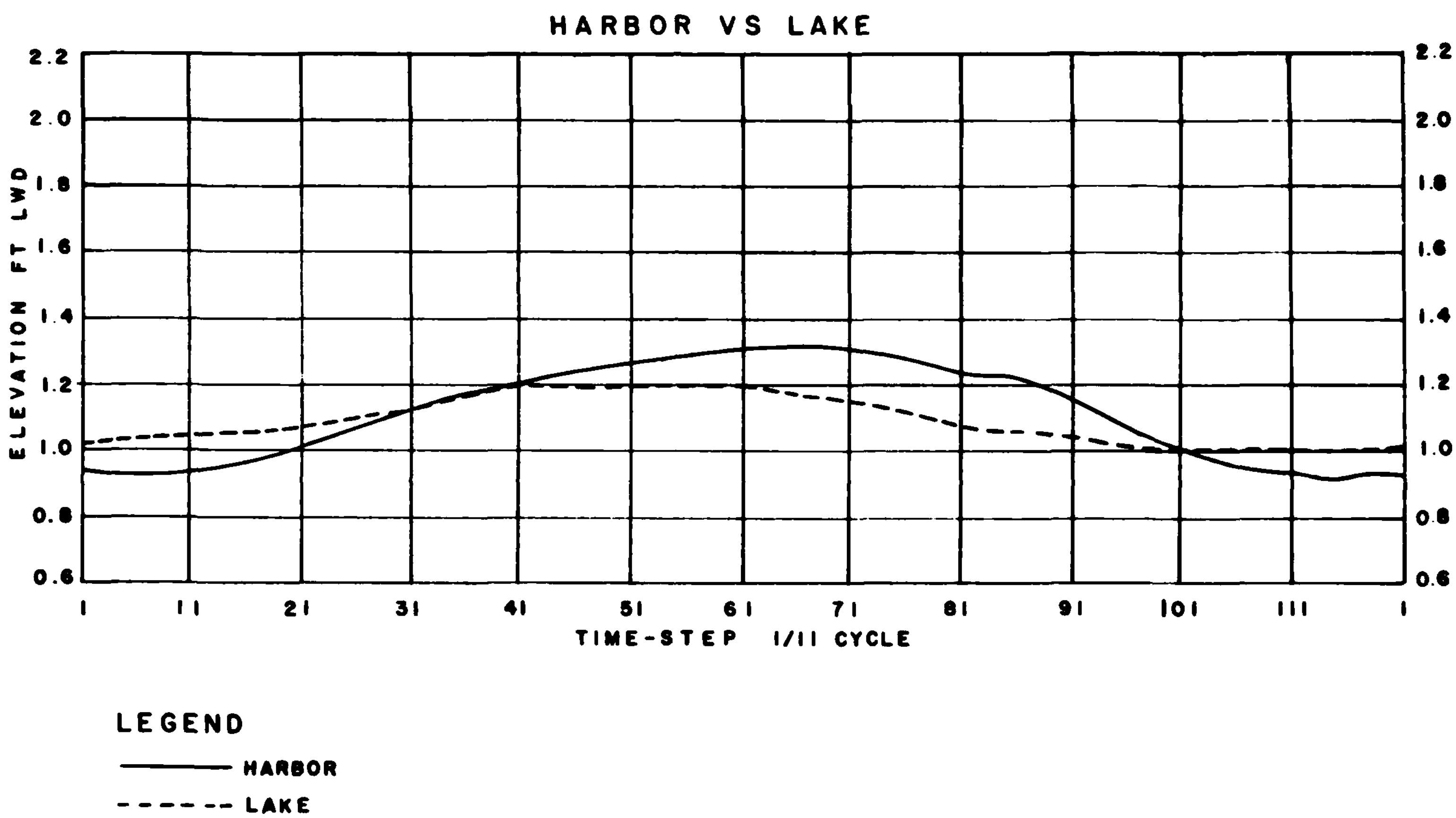
FPS, PROTOTYPE

SURFACE CURRENTS
BASE
TIME-STEP 111
W/WAVES FROM 359 °

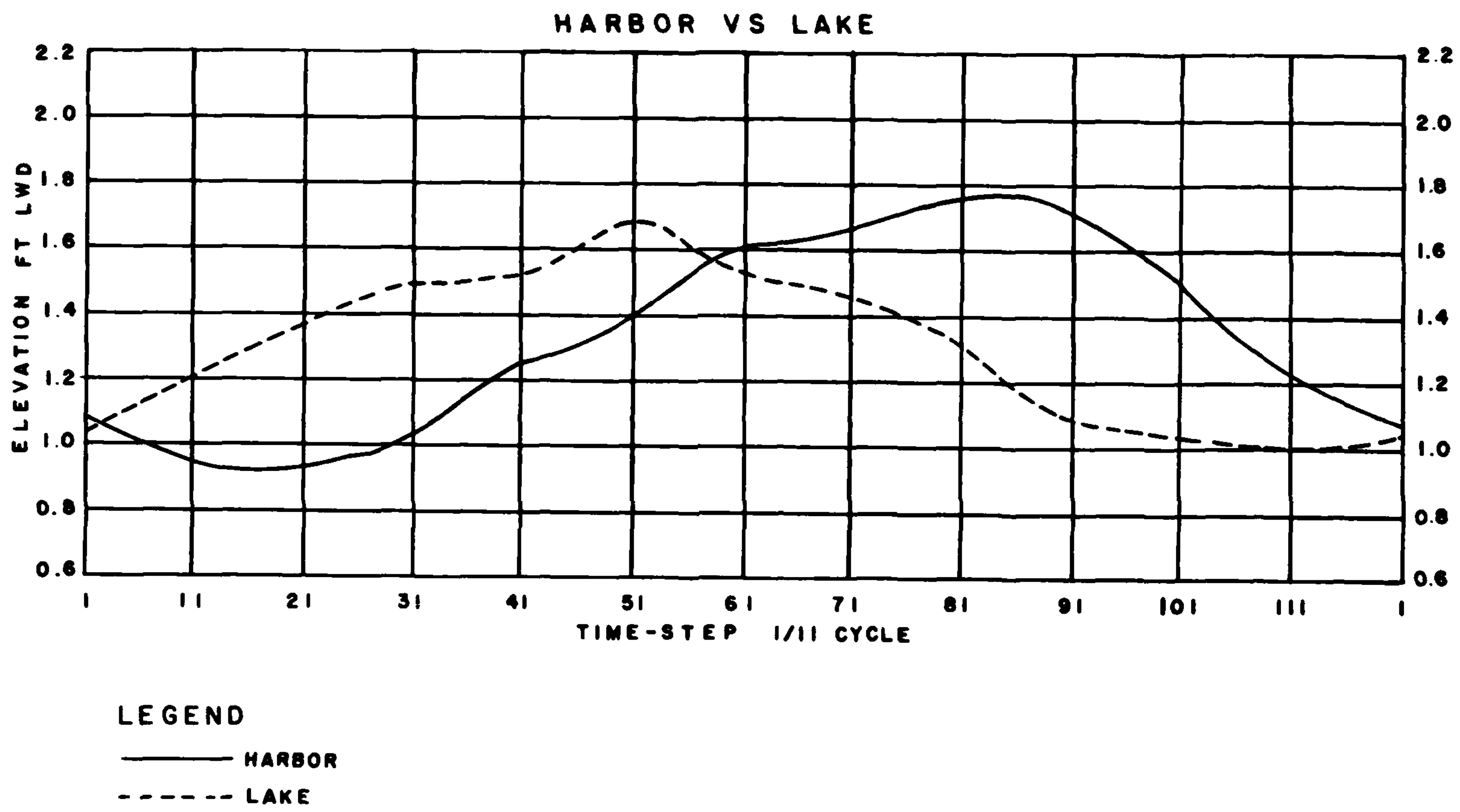


GAGE LOCATIONS

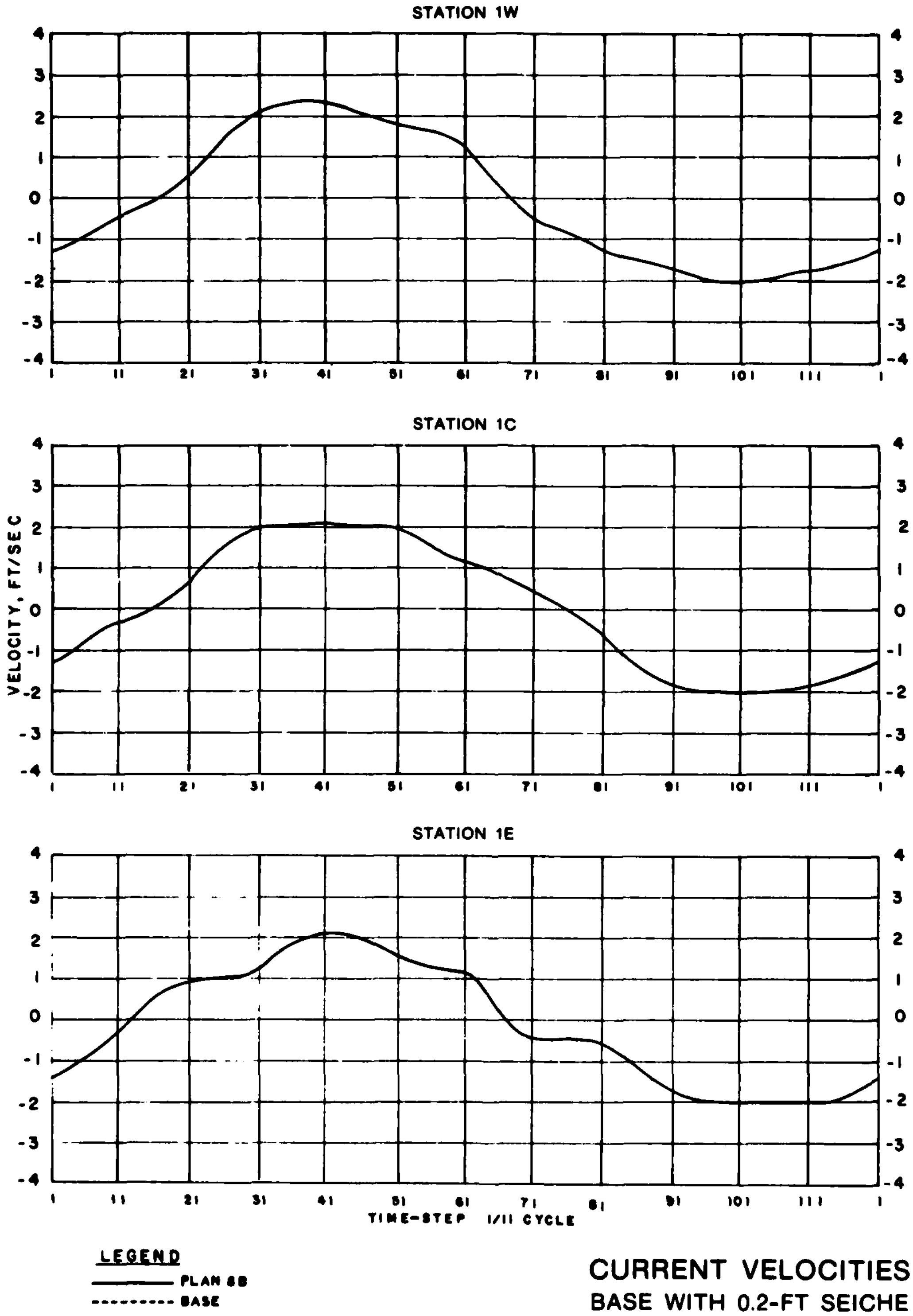
PLATE 261



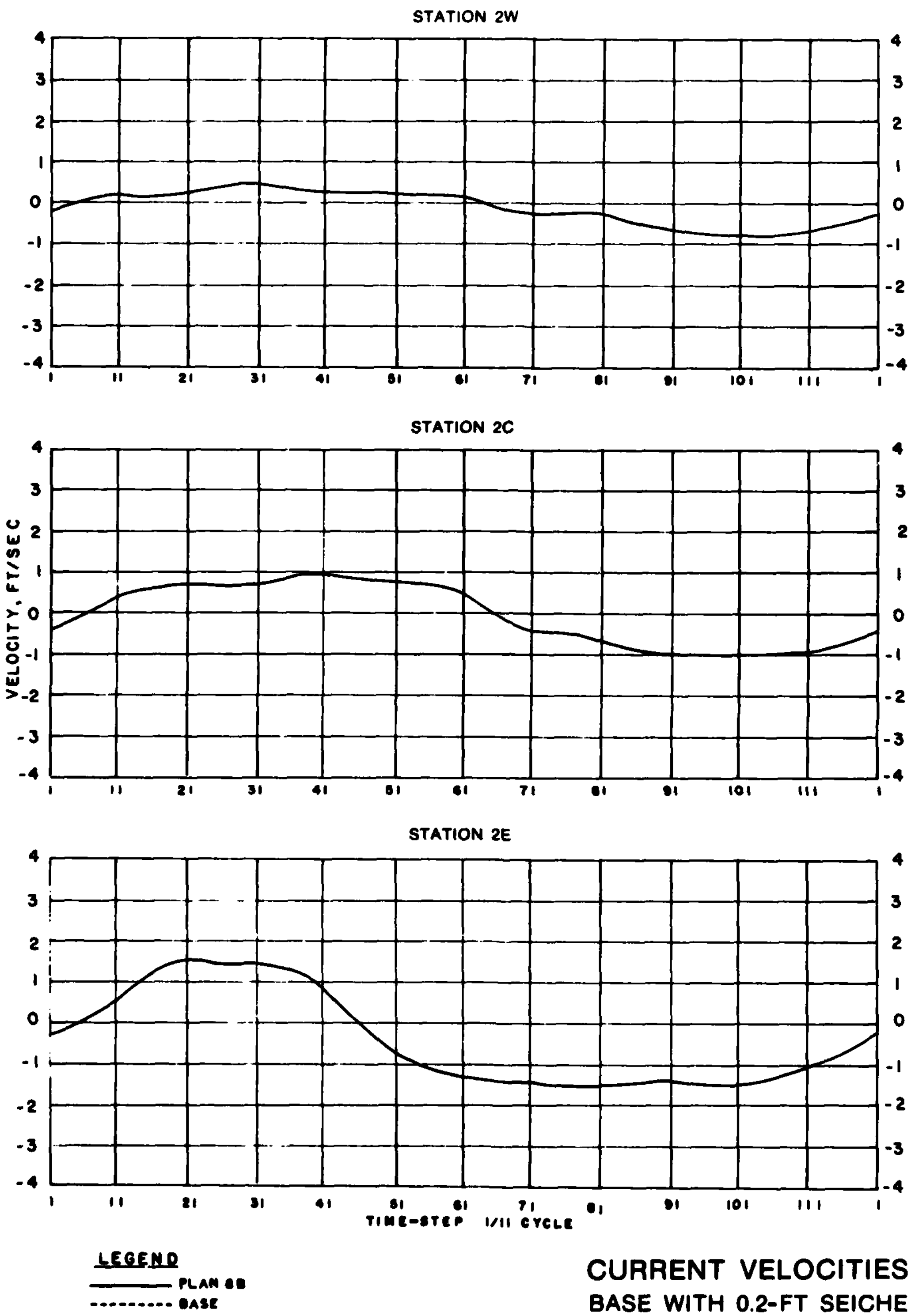
WATER-SURFACE ELEVATION
BASE WITH 0.2-FT SEICHE



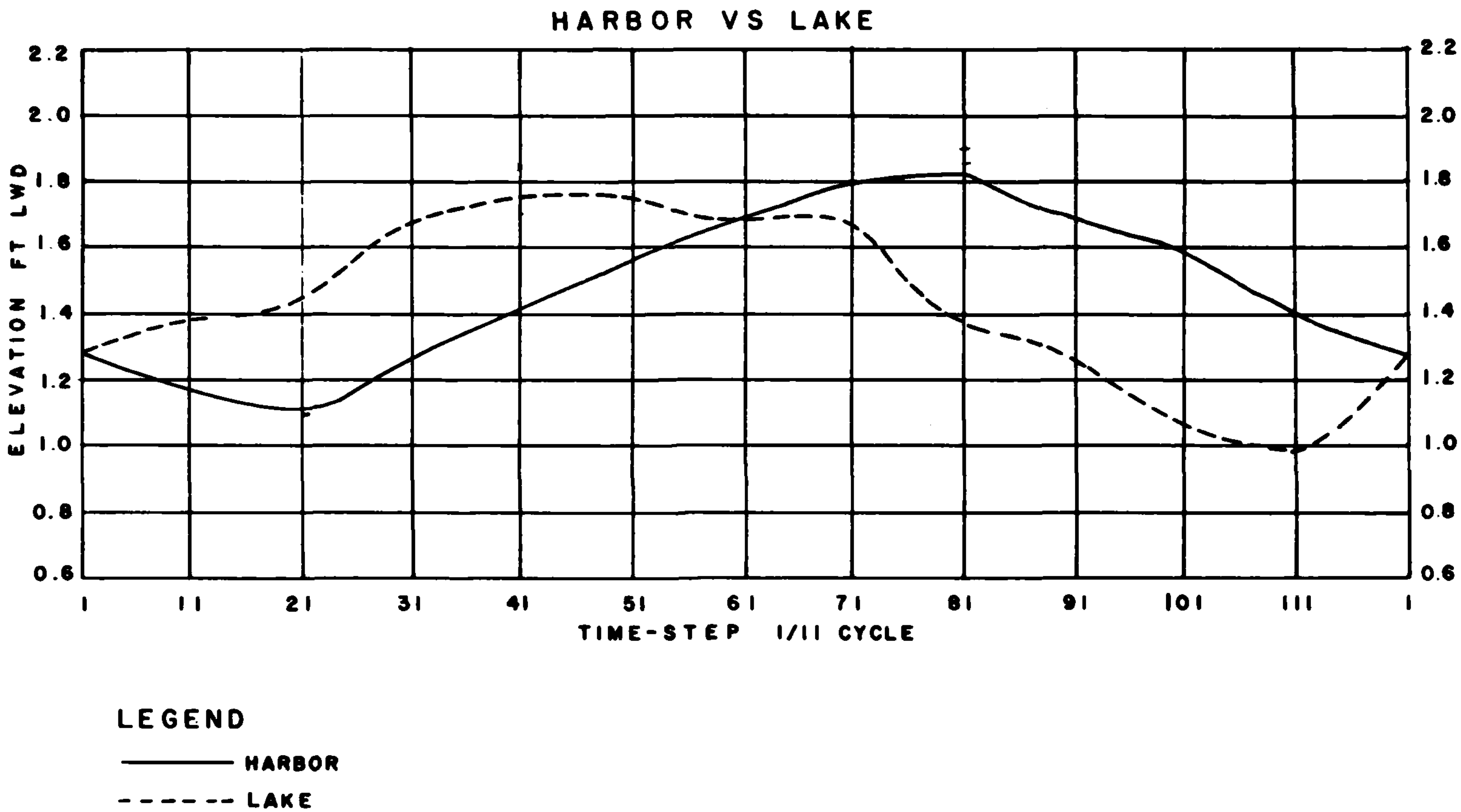
WATER-SURFACE ELEVATION
BASE WITH 0.6-FT SEICHE



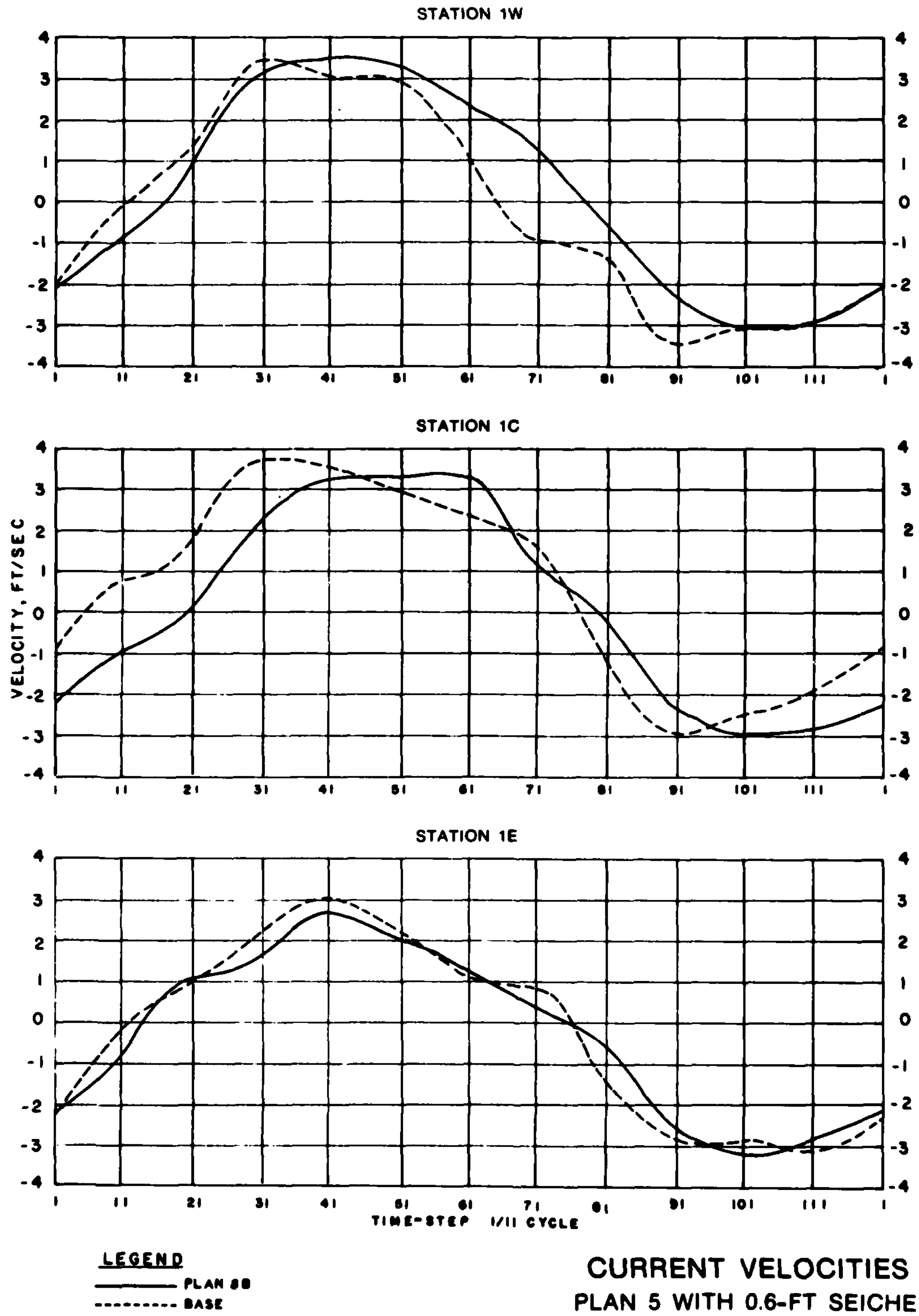
CURRENT VELOCITIES
BASE WITH 0.2-FT SEICHE
STATIONS 1W, 1C, AND 1E



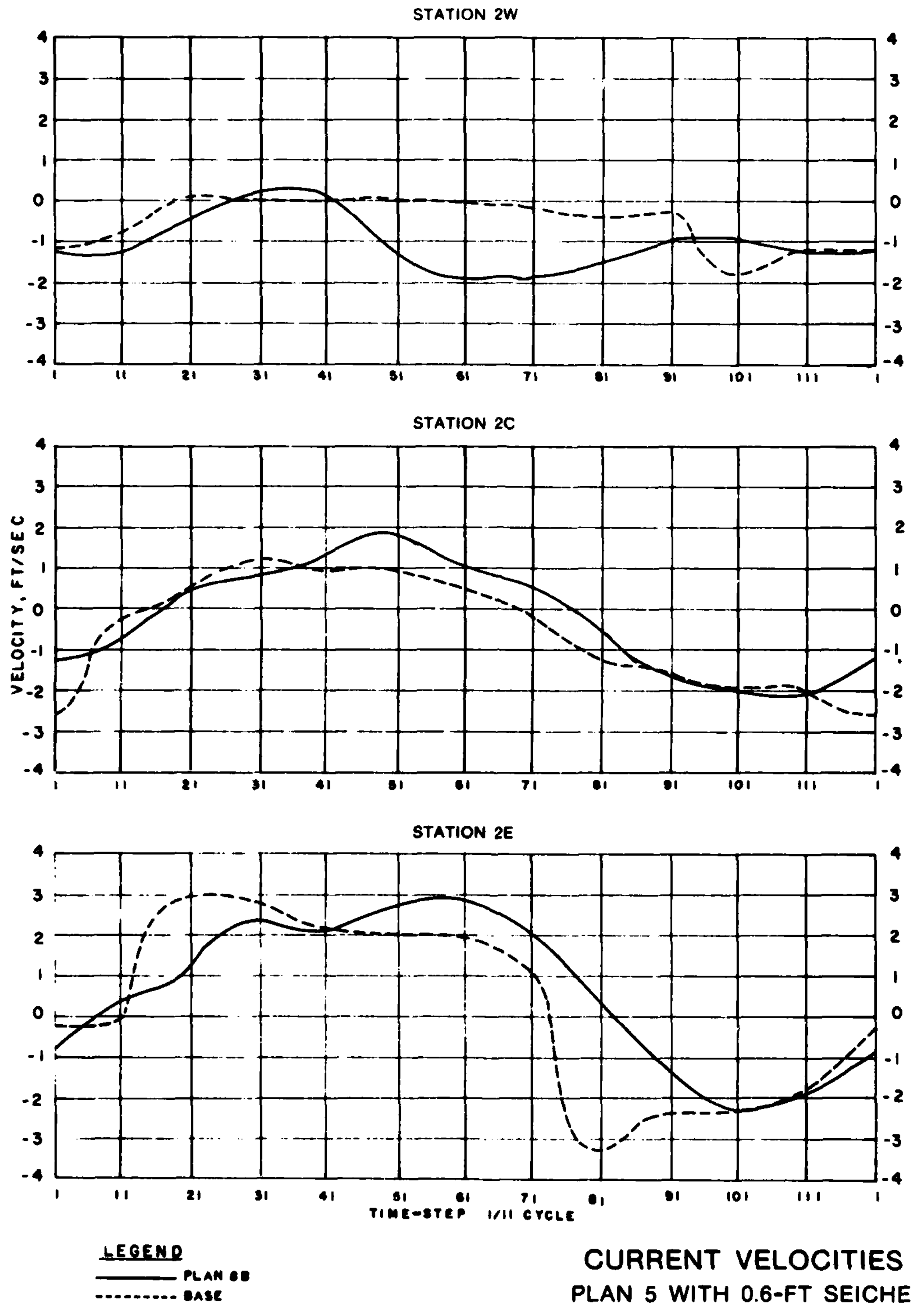
CURRENT VELOCITIES
BASE WITH 0.2-FT SEICHE
STATIONS 2W, 2C, AND 2E



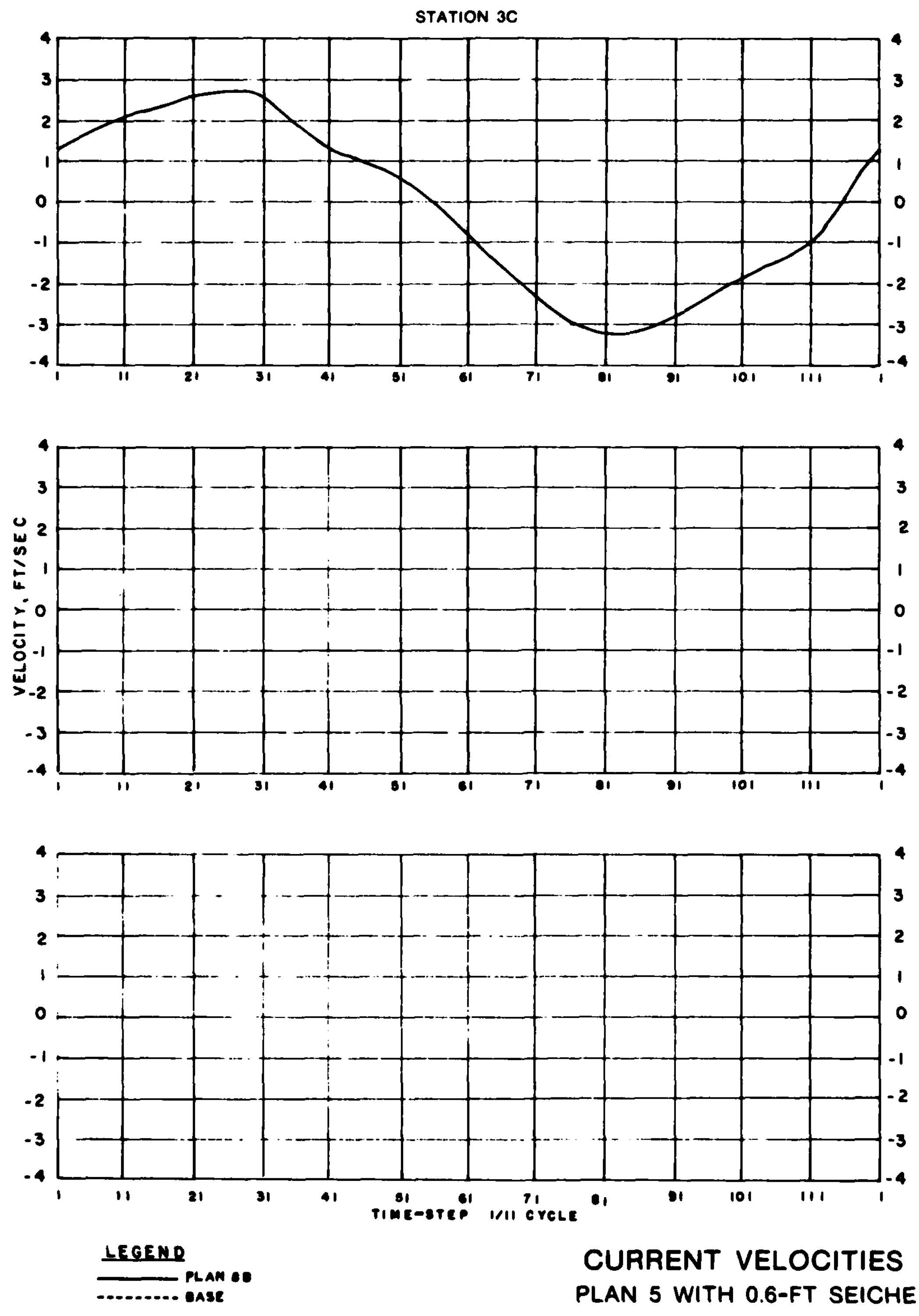
WATER-SURFACE ELEVATION
PLAN 5 WITH 0.6-FT SEICHE



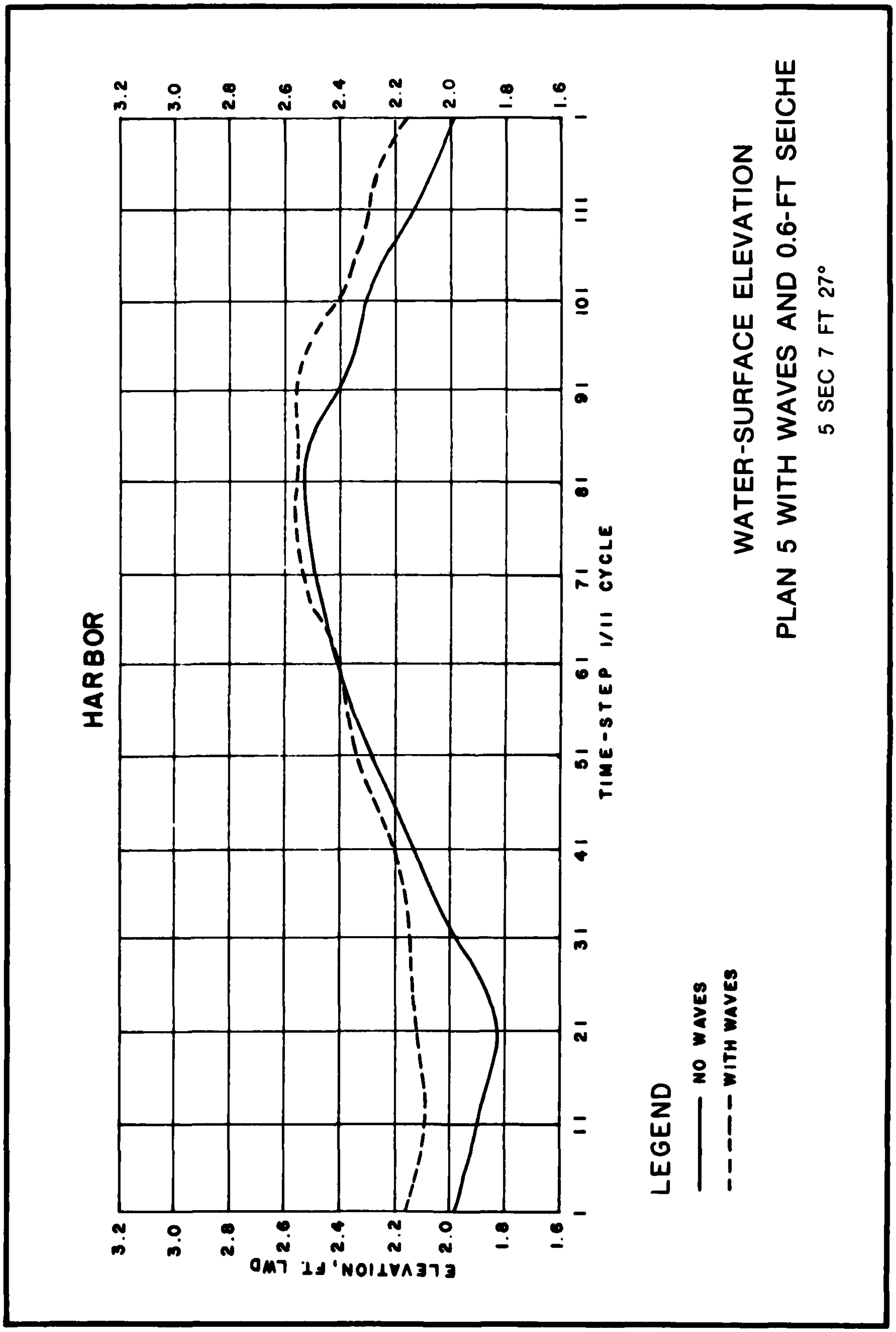
CURRENT VELOCITIES
PLAN 5 WITH 0.6-FT SEICHE
STATIONS 1W, 1C, AND 1E



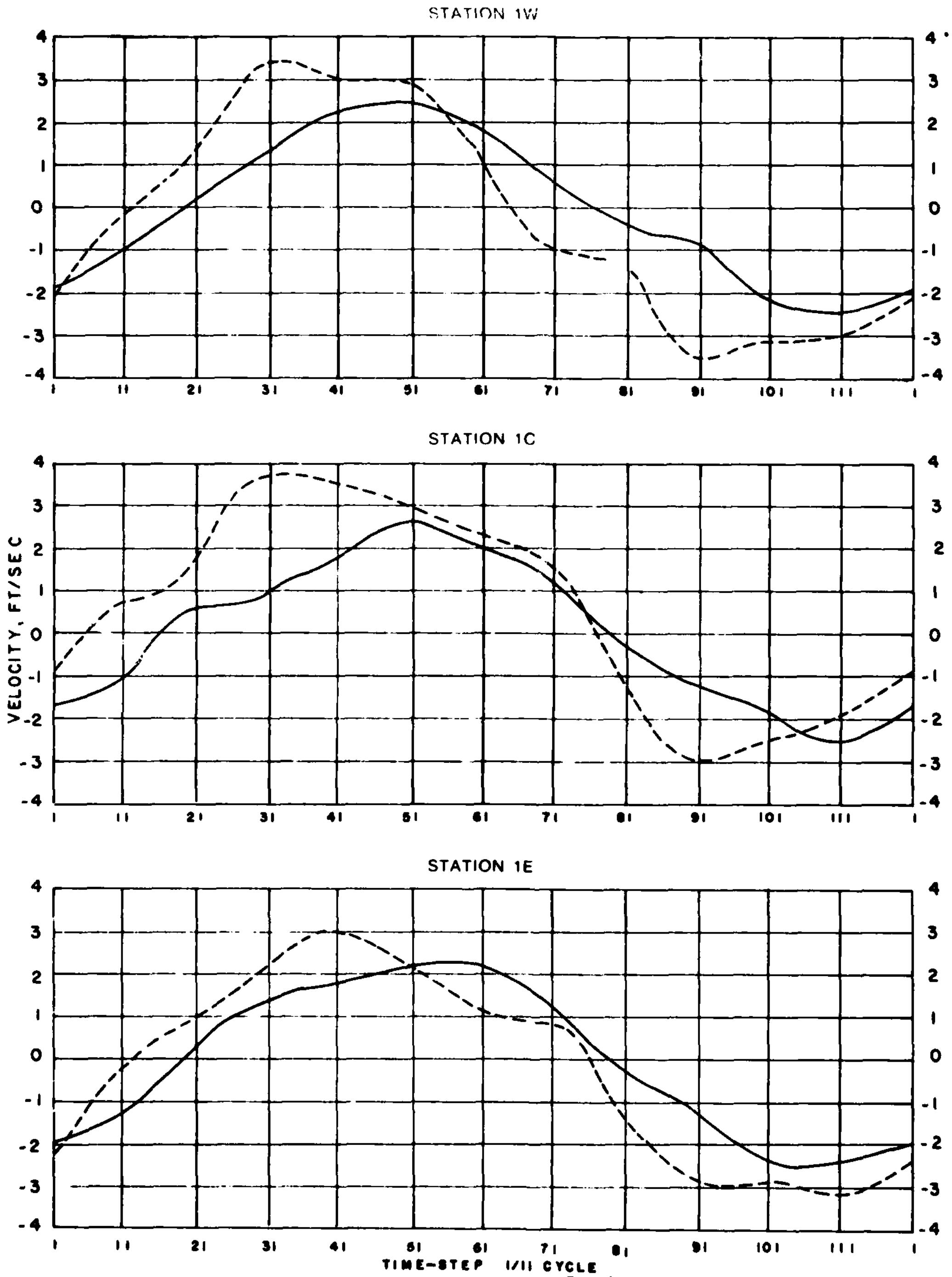
CURRENT VELOCITIES
PLAN 5 WITH 0.6-FT SEICHE
STATIONS 2W, 2C, AND 2E



CURRENT VELOCITIES
PLAN 5 WITH 0.6-FT SEICHE
STATION 3C

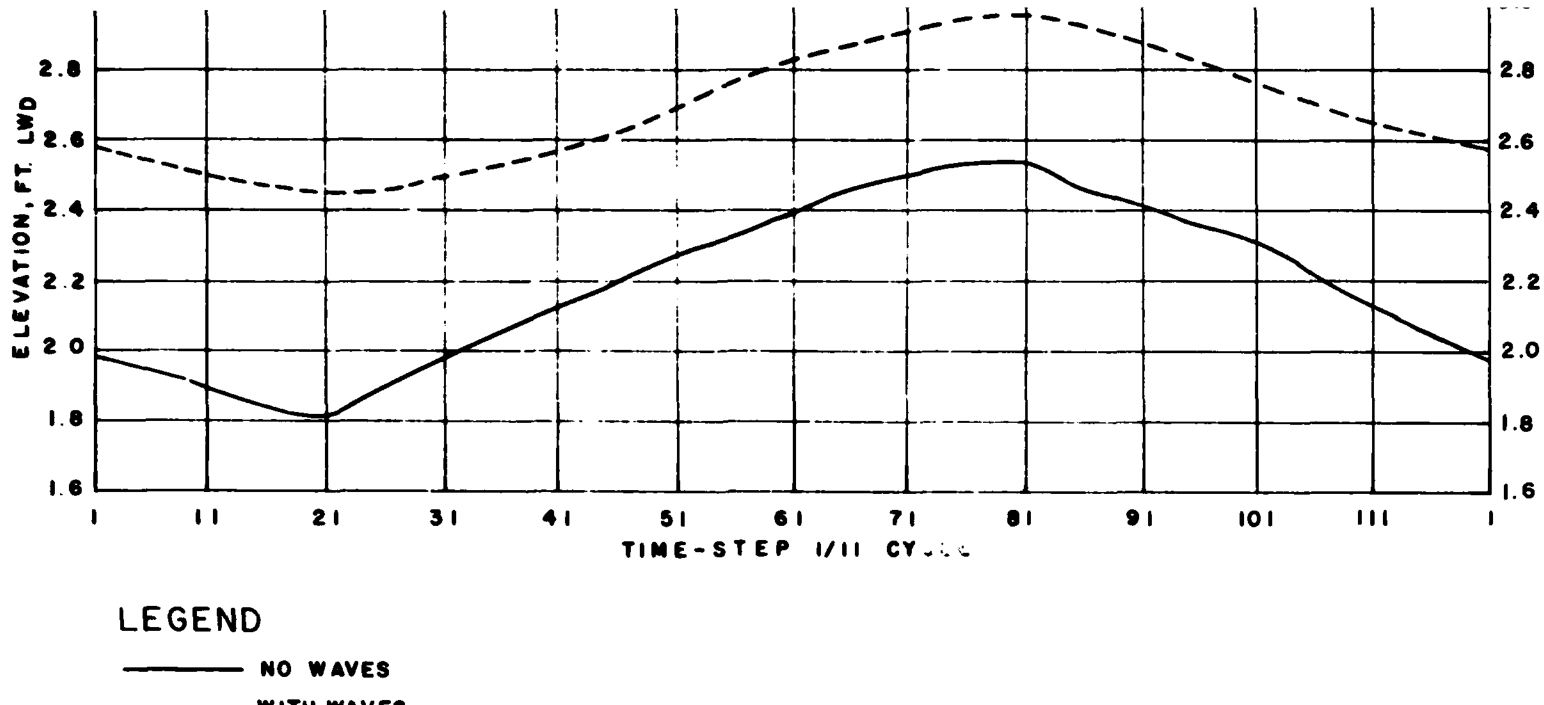


HARBOR
WATER-SURFACE ELEVATION
PLAN 5 WITH WAVES AND 0.6-FT SEICHE
5 SEC 7 FT 27°
LEGEND
NO WAVES
WITH WAVES
TIME-STEP 1/11 CYCLE
ELEVATION, FT LWD
1
11
21
31
41
51
61
71
81
91
101
111
1
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2

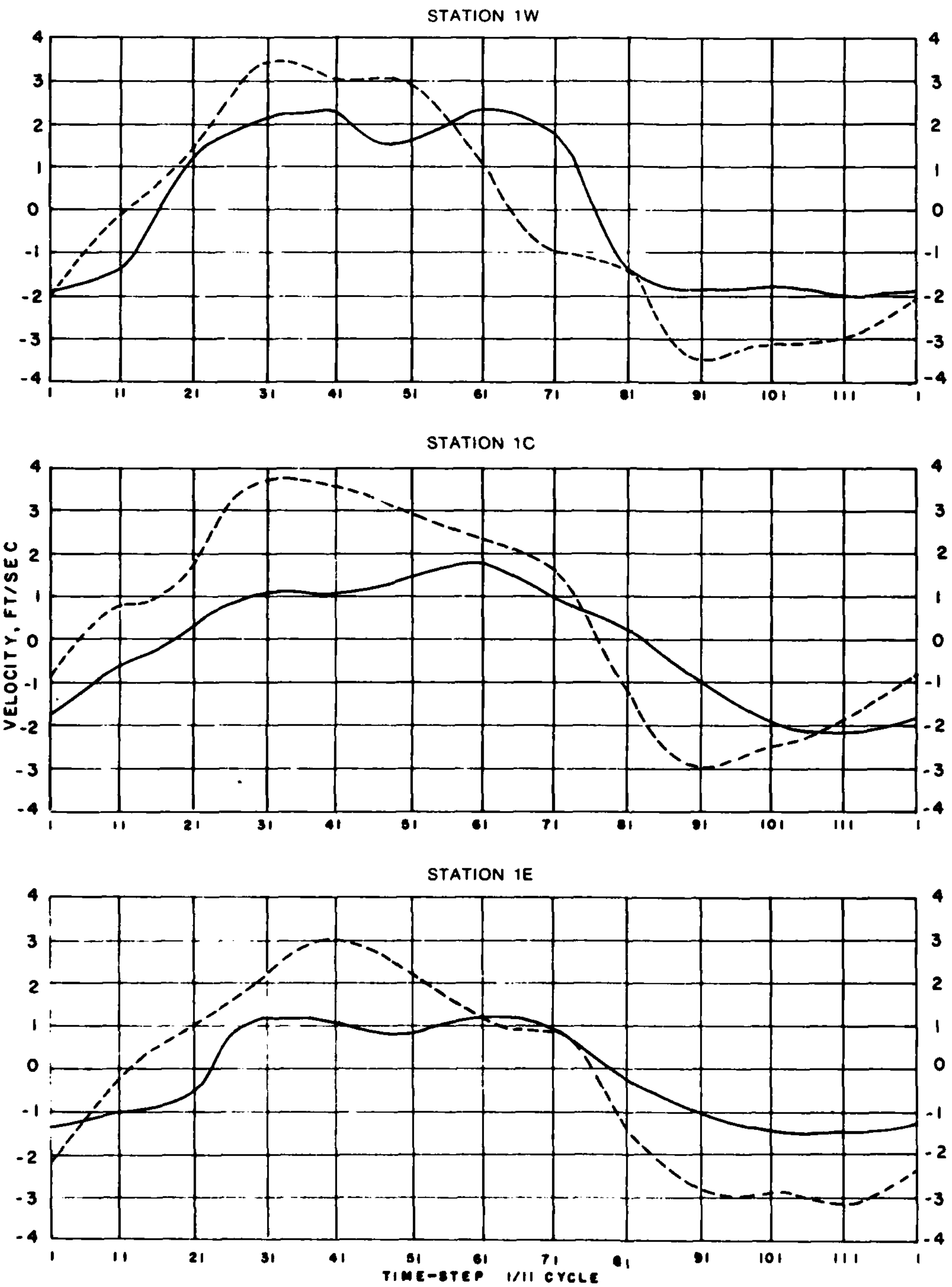


LEGEND
——— PLAN 8B
- - - - - BASE

CURRENT VELOCITIES
PLAN 5 WITH WAVES AND 0.6-FT SEICHE
STATIONS 1W, 1C, AND 1E
5 SEC 7 FT 217'



WATER-SURFACE ELEVATION
PLAN 5 WITH WAVES AND 0.6-FT SEICHE
9 SEC 8 FT 304°



LEGEND
PLAN 5B
BASE

CURRENT VELOCITIES

PLAN 5 WITH WAVES AND 0.6-FT SEICHE

STATIONS 1W, 1C, AND 1E

9 SEC 8 FT 304°

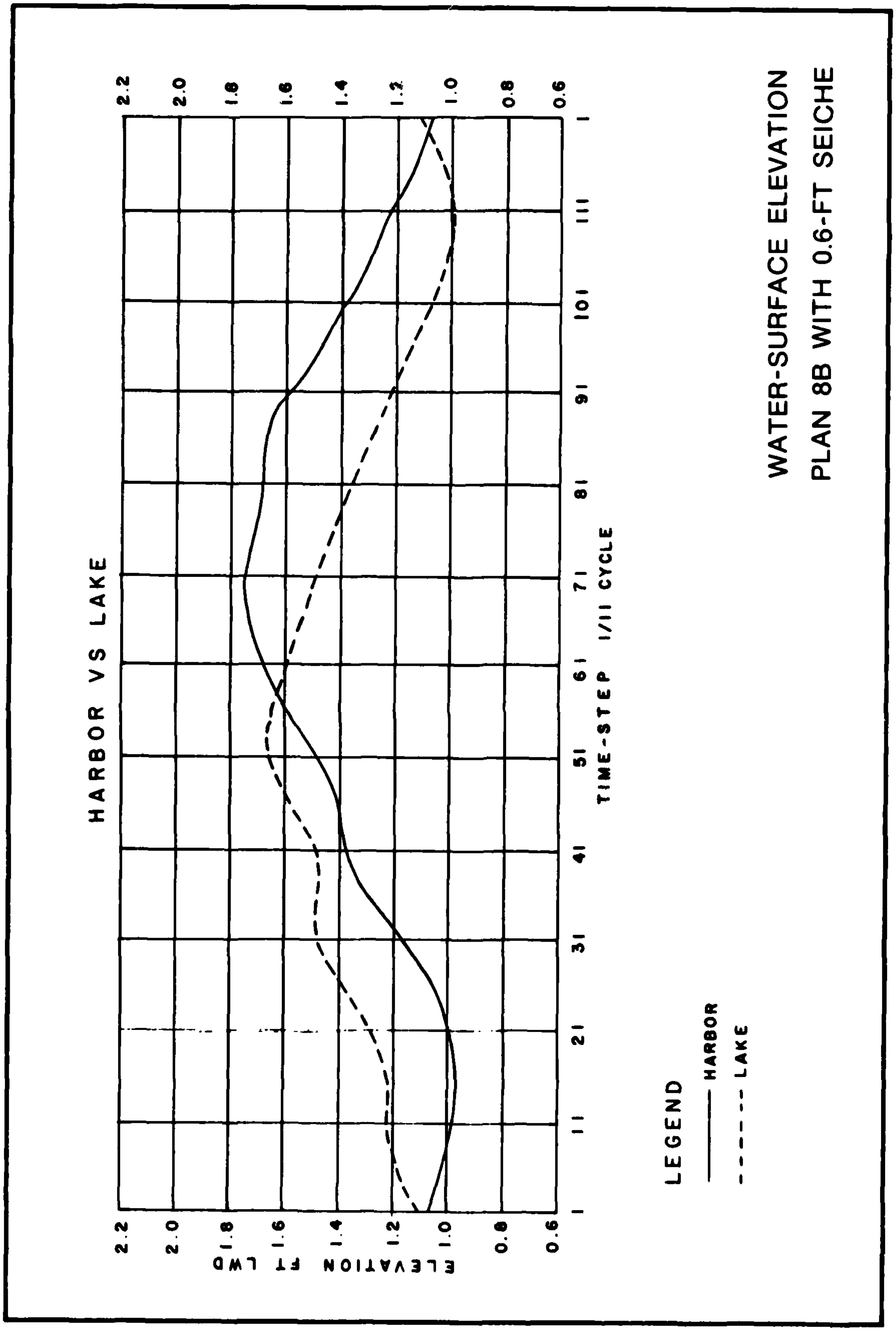
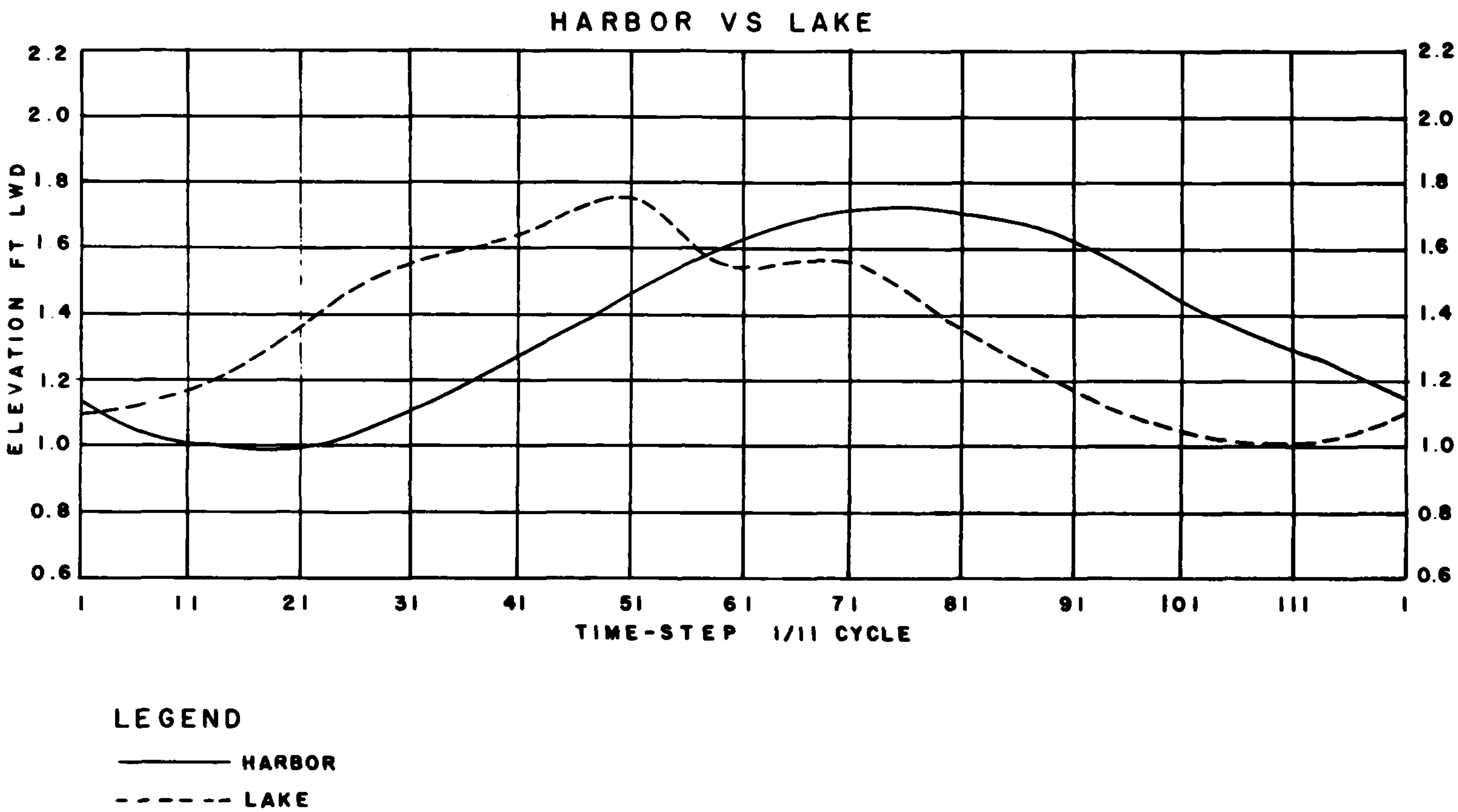
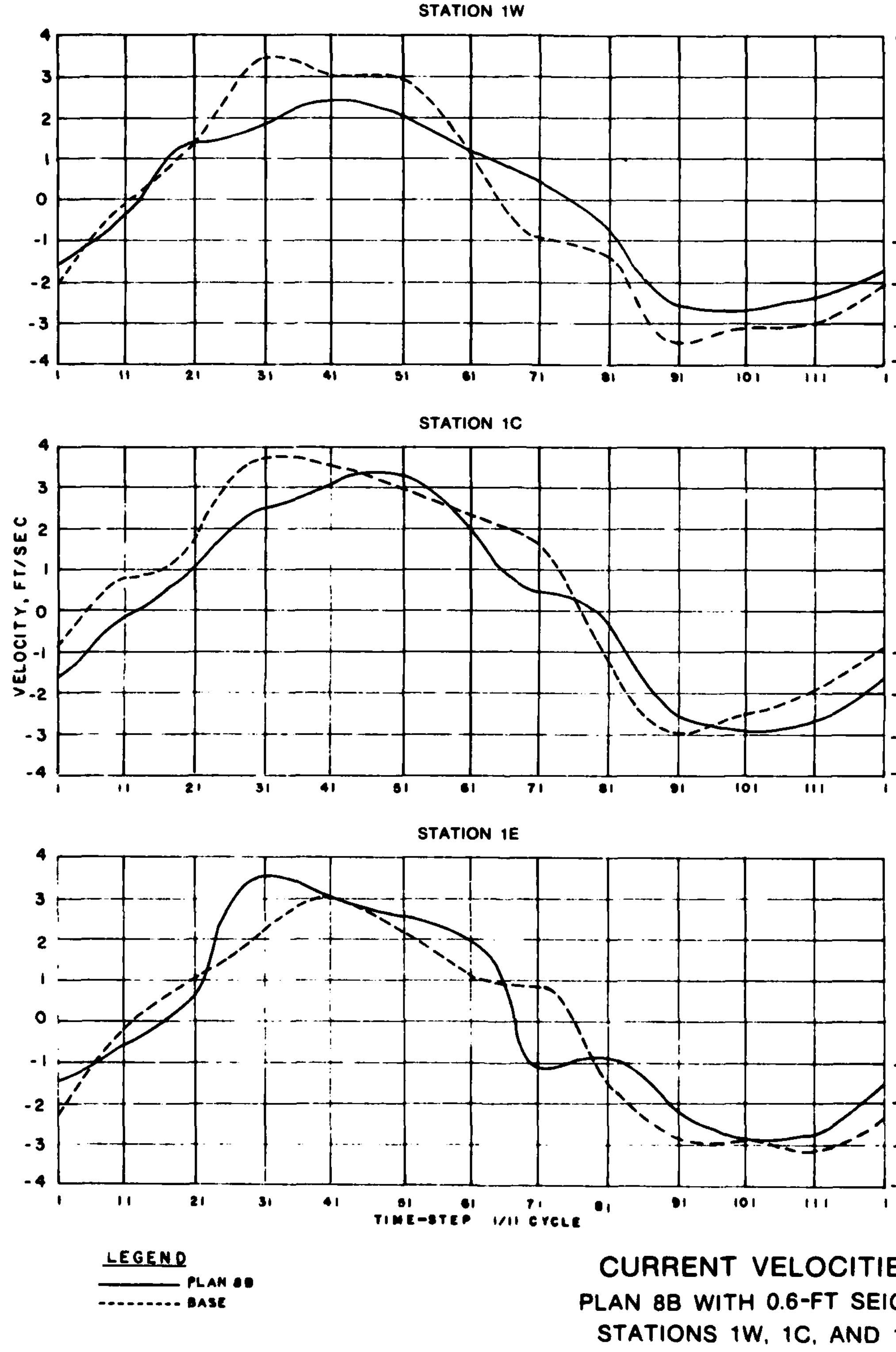

HARBOR VS LAKE
ELEVATION FT LWD
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
1
11
21
31
41
51
61
71
81
91
101
111
TIME-STEP 1/11 CYCLE
LEGEND
HARBOR
LAKE
WATER-SURFACE ELEVATION
PLAN 8B WITH 0.6-FT SEICHE

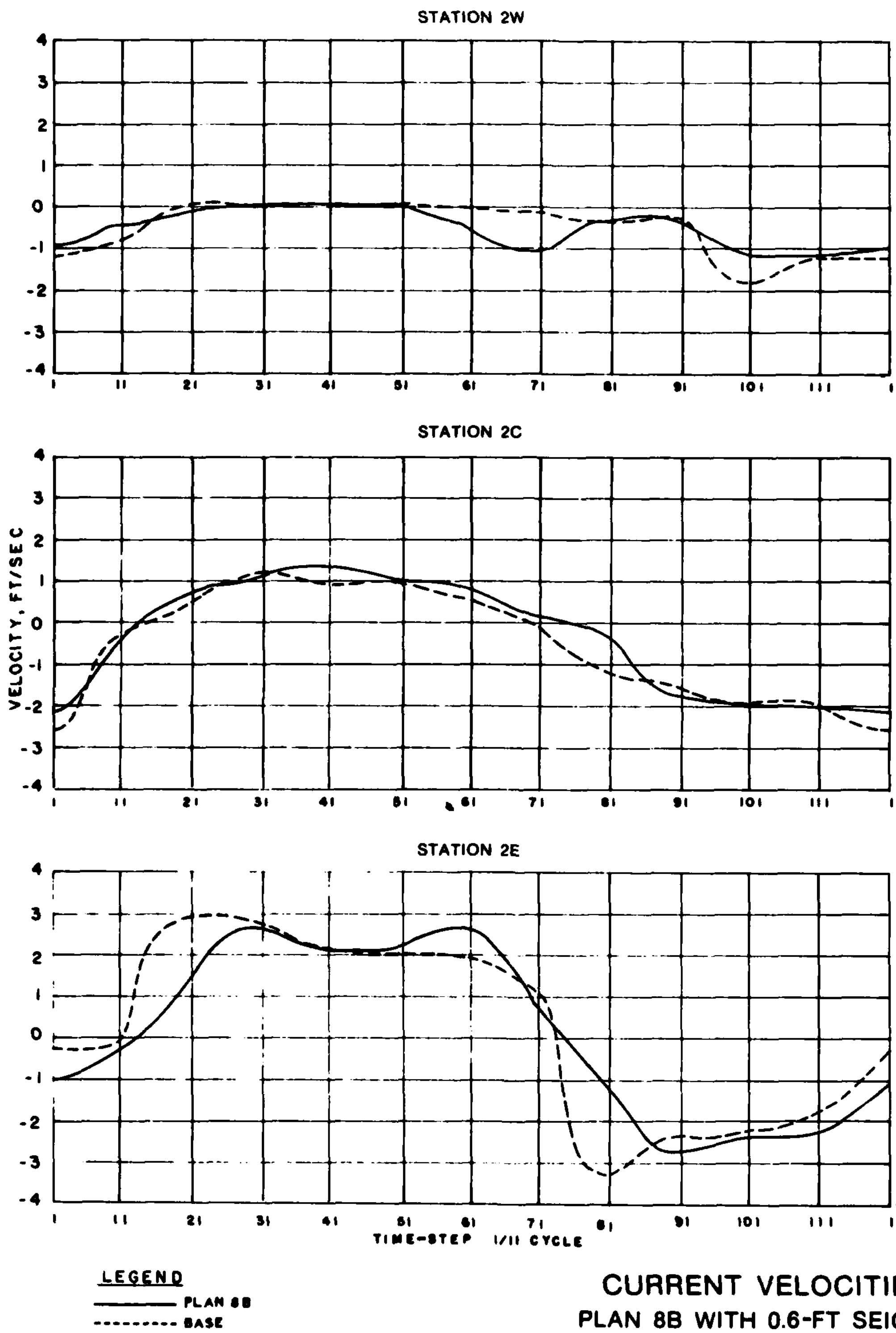
PLATE 274



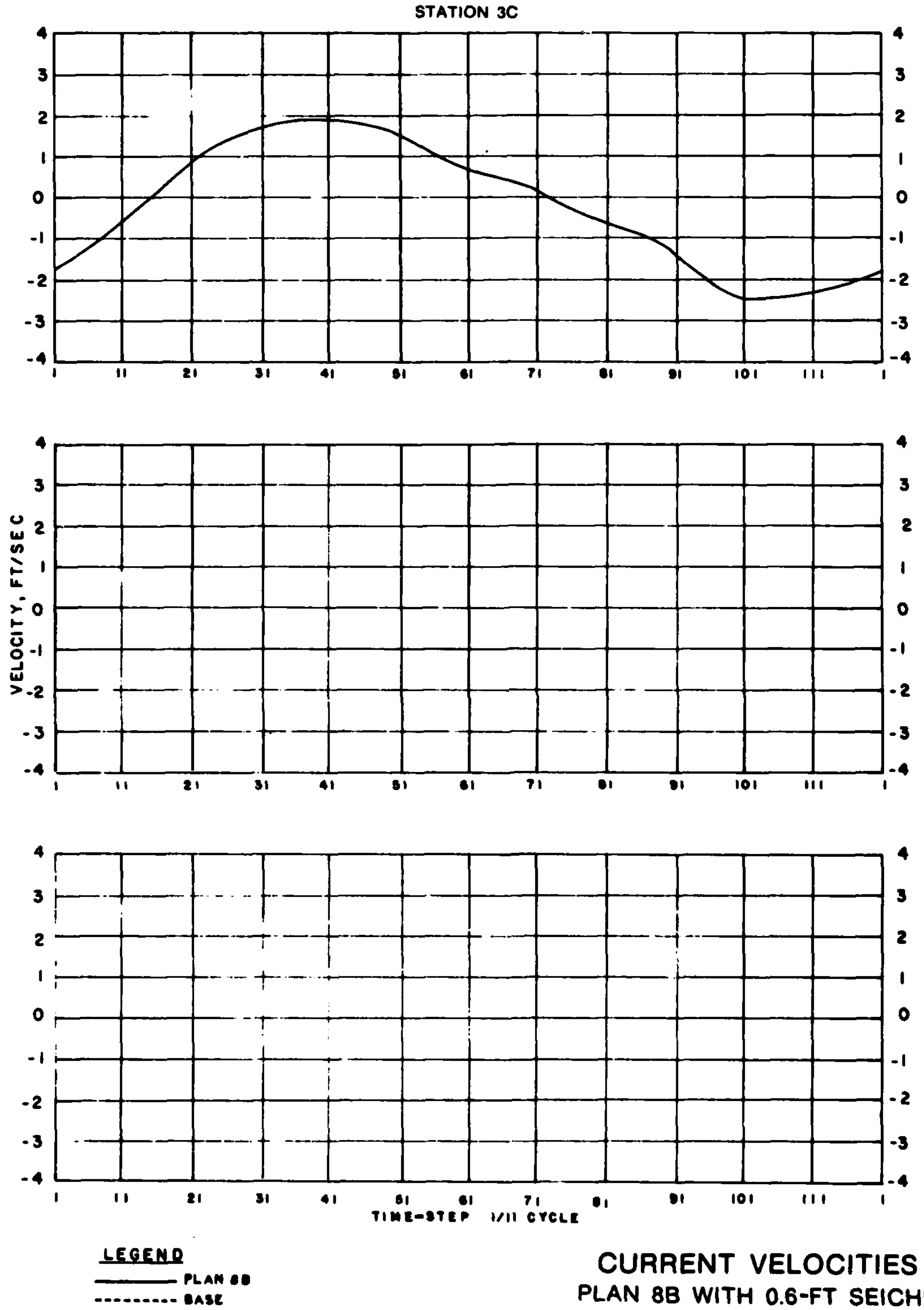
WATER-SURFACE ELEVATION
PLAN 8B WITH GAP CLOSED
AND 0.6-FT SEICHE



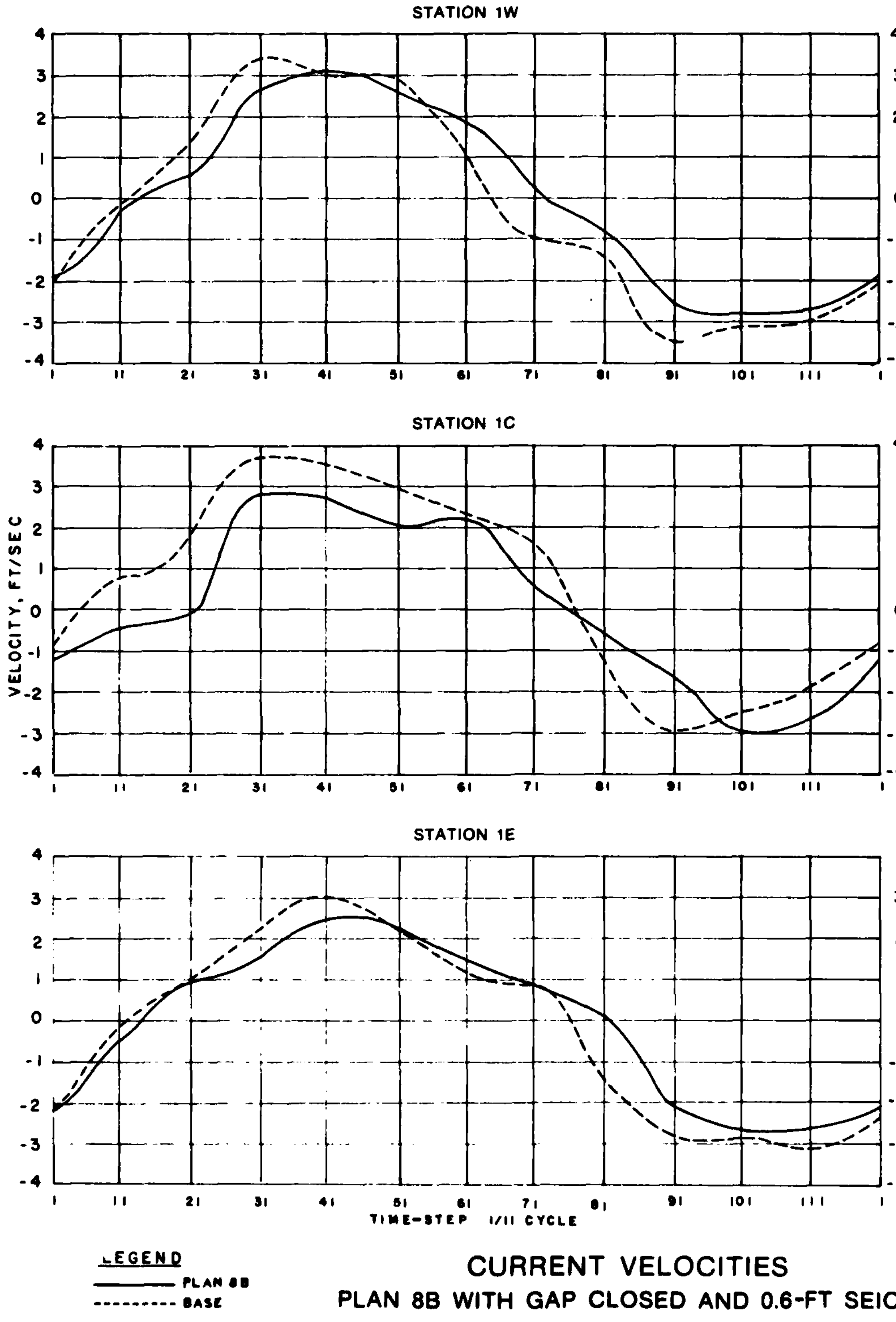
CURRENT VELOCITIES
PLAN 8B WITH 0.6-FT SEICHE
STATIONS 1W, 1C, AND 1E



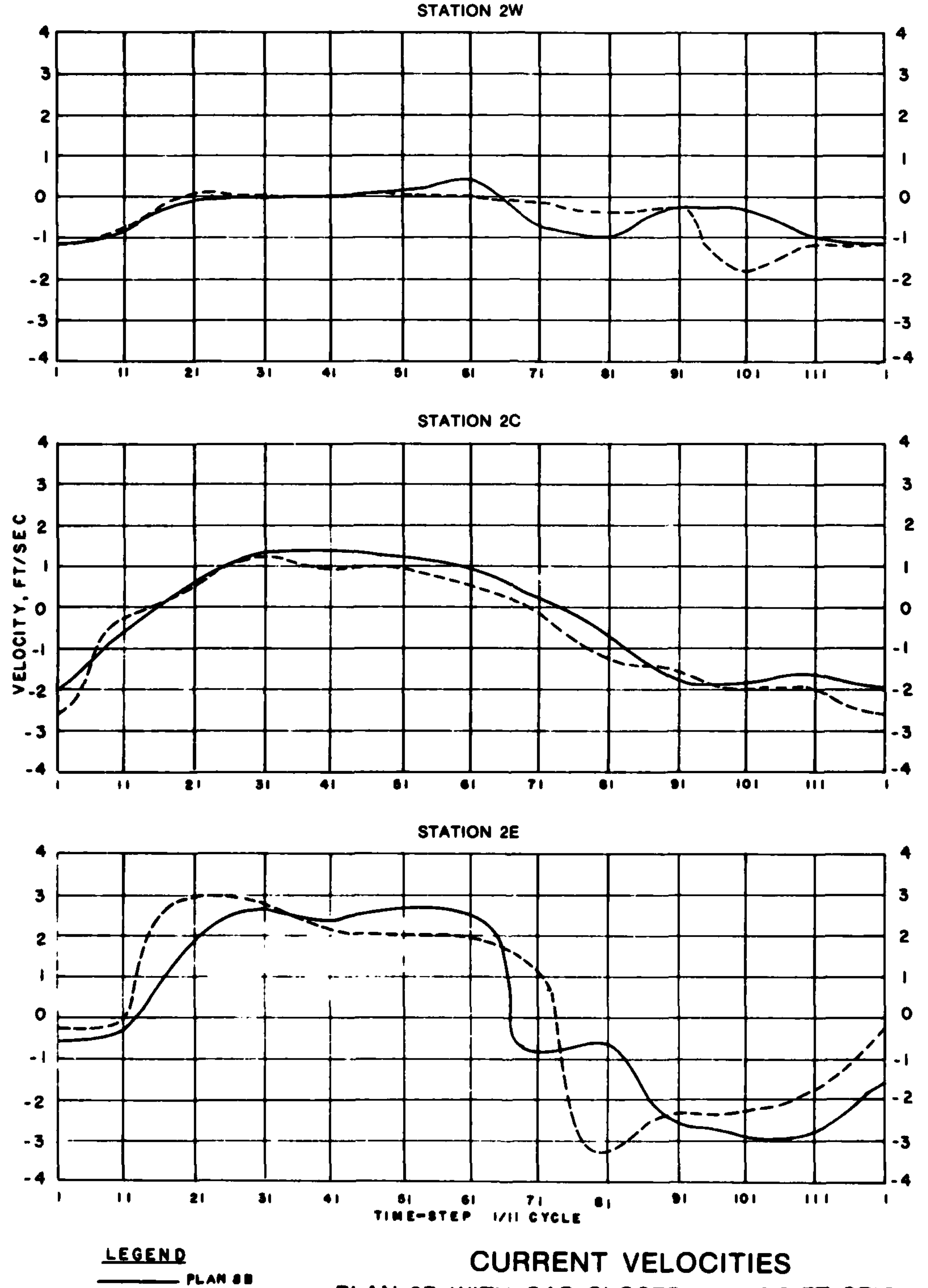
CURRENT VELOCITIES
PLAN 8B WITH 0.6-FT SEICHE
STATIONS 2W, 2C, AND 2E



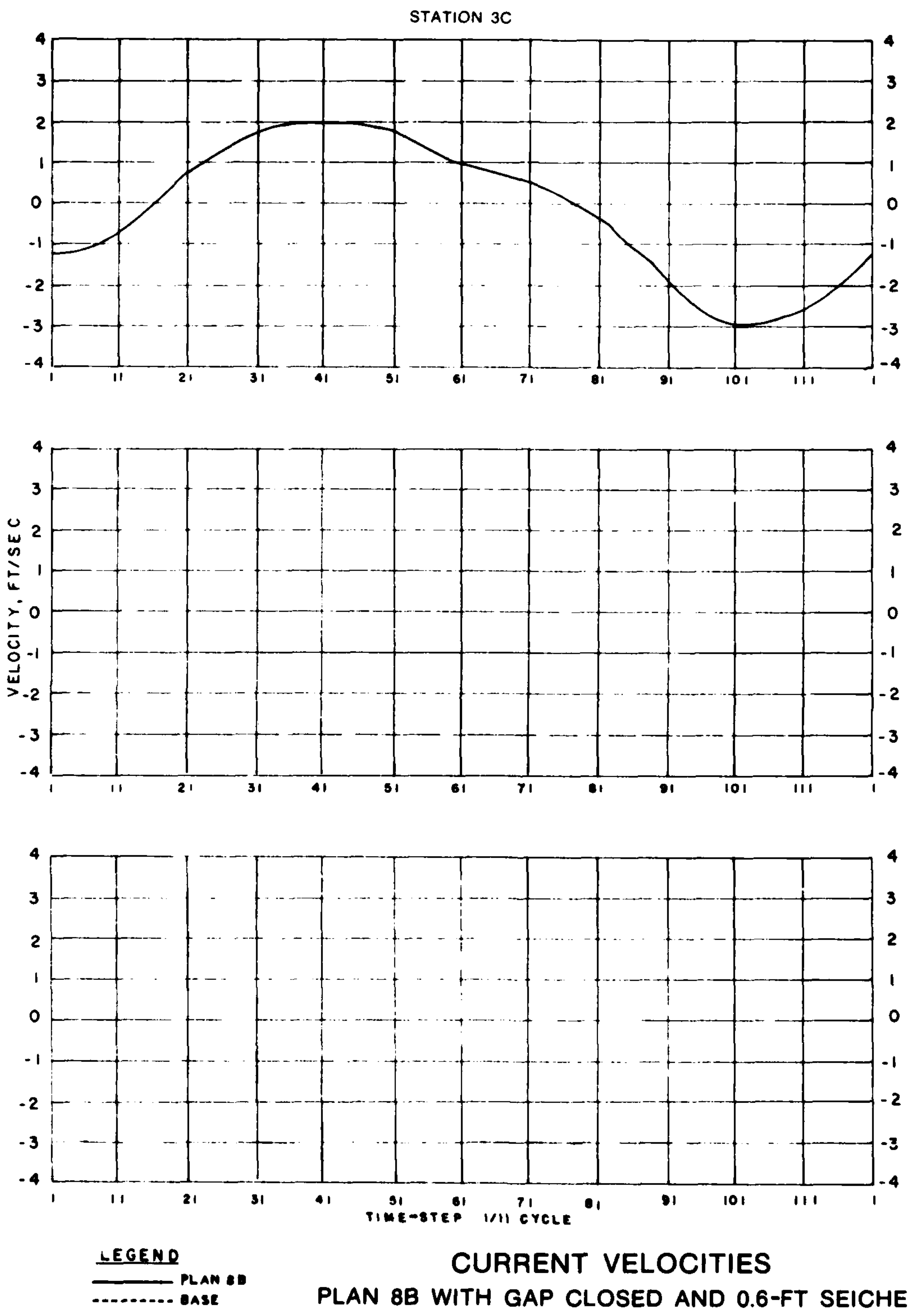
CURRENT VELOCITIES
PLAN 8B WITH 0.6-FT SEICHE
STATION 3C



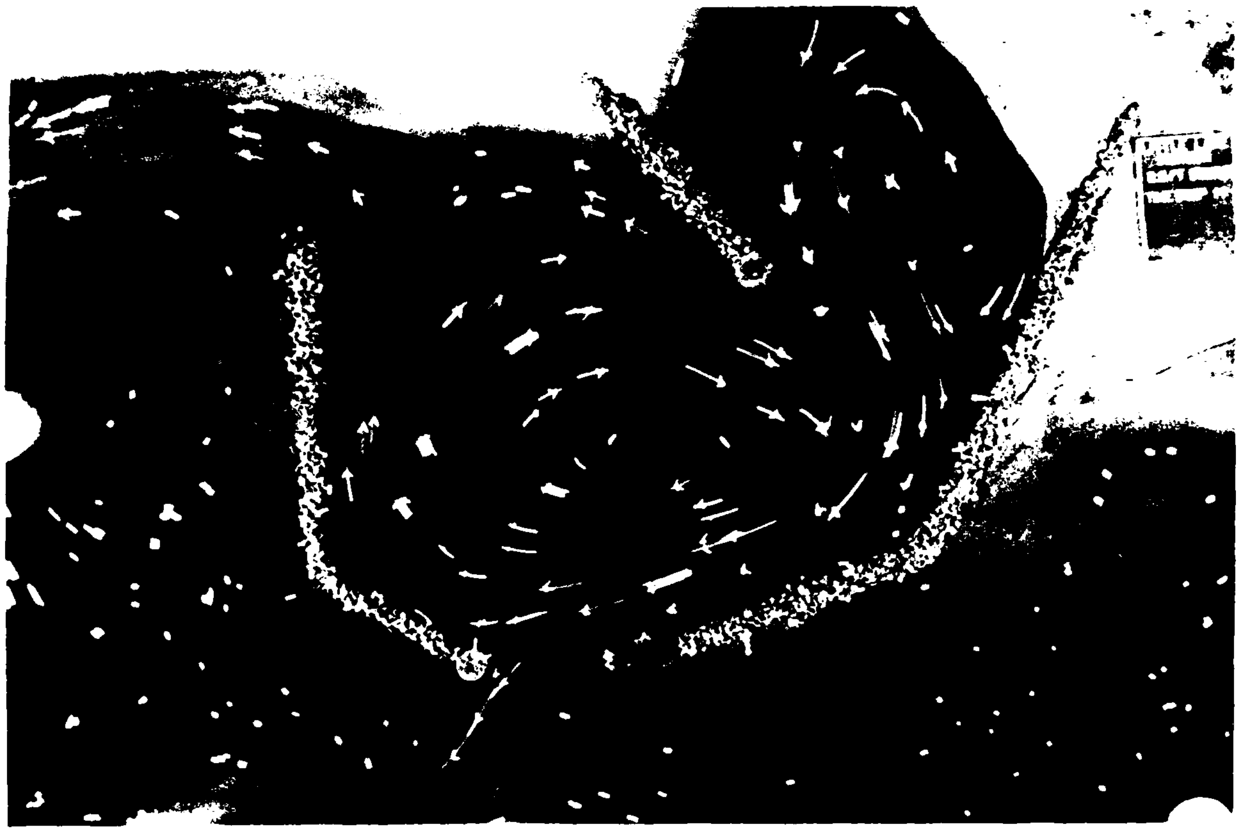
CURRENT VELOCITIES
PLAN 8B WITH GAP CLOSED AND 0.6-FT SEICHE
STATIONS 1W, 1C, AND 1E



CURRENT VELOCITIES
PLAN 8B WITH GAP CLOSED AND 0.6-FT SEICHE
STATIONS 2W, 2C, AND 2E



CURRENT VELOCITIES
PLAN 8B WITH GAP CLOSED AND 0.6-FT SEICHE
STATION 3C

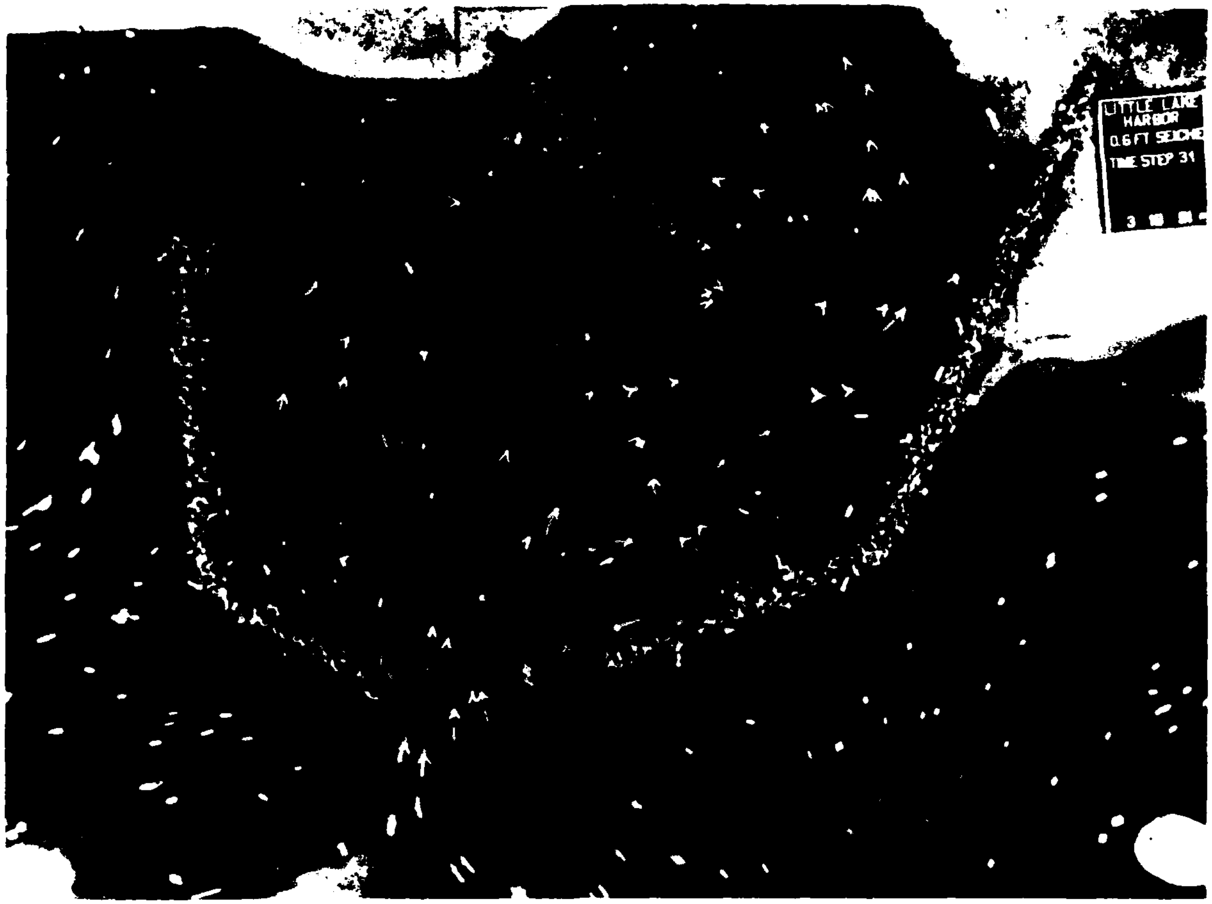


CONDITION PLAN 8B
SEICHE HEIGHT 0.6 FT

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

SURFACE CURRENTS
PLAN 8B
TIME-STEP 11

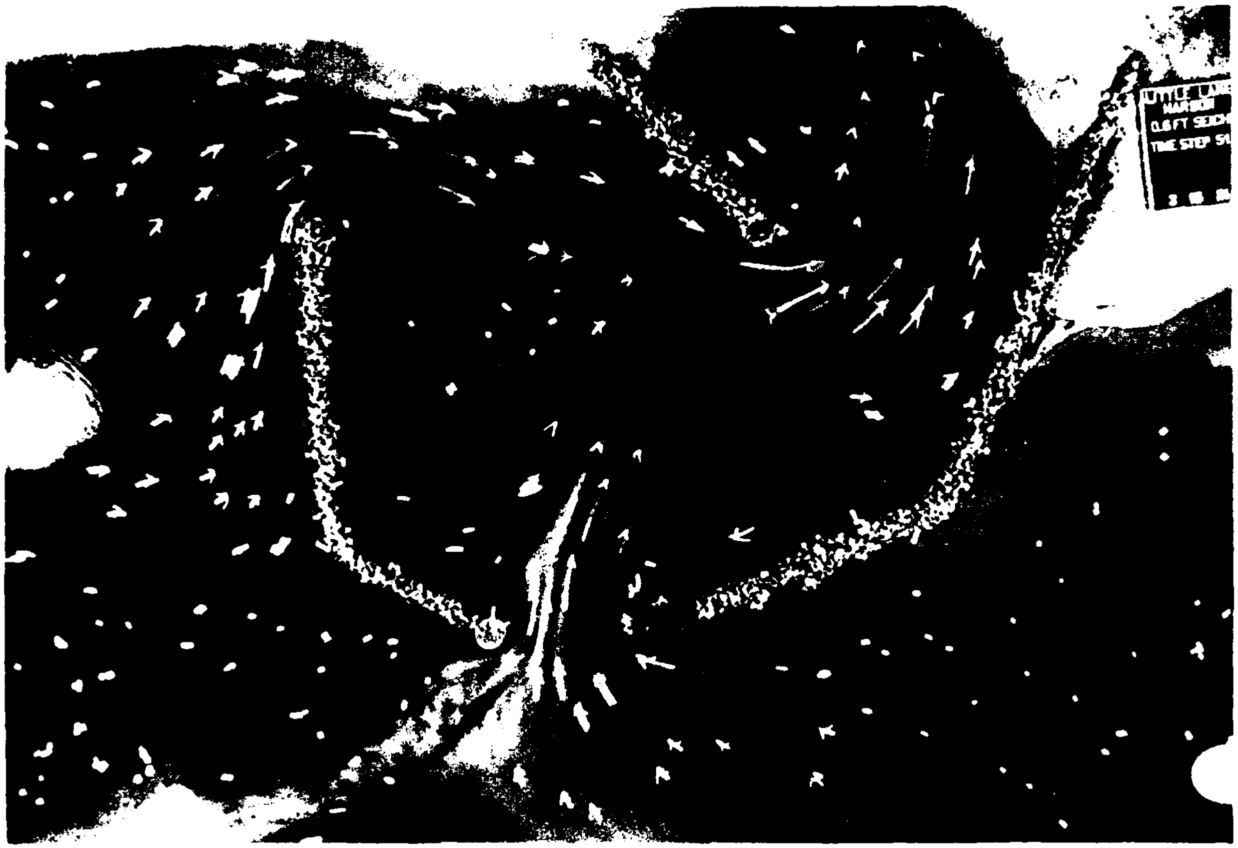


CONDITION PLAN 8B
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B
TIME-STEP 31



CONDITION PLAN 8B
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B
TIME-STEP 51

CONDITION PLAN 8B
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

VELOCITY SCALE

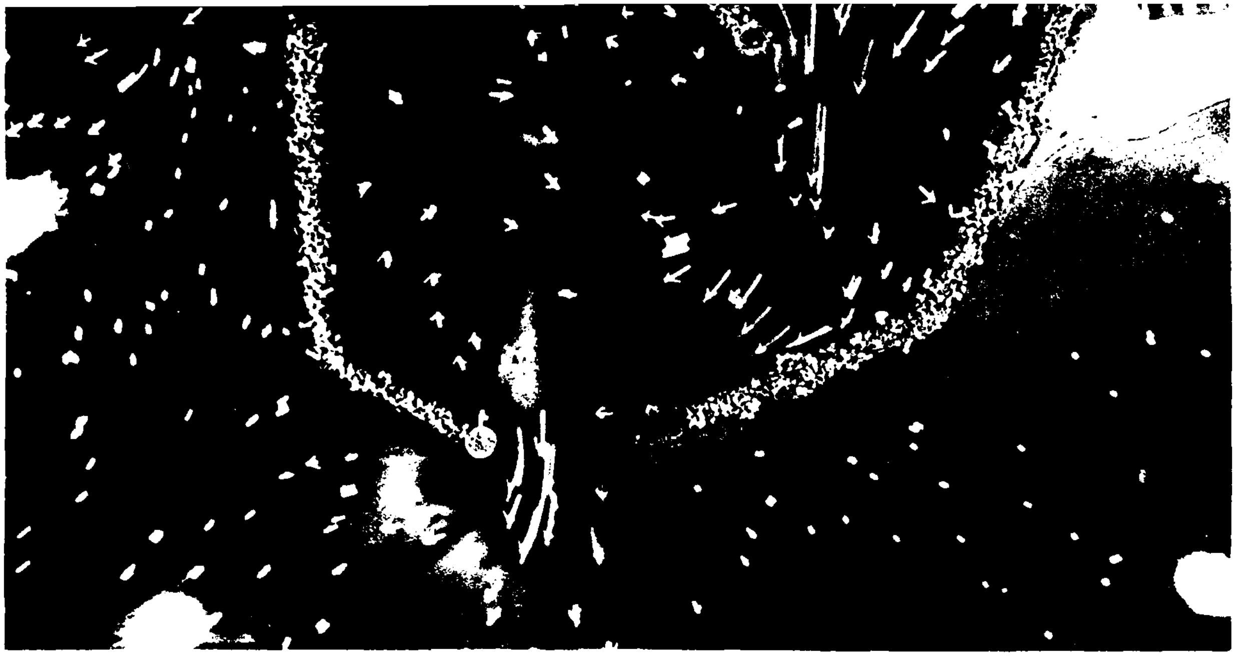
0 2 4 6 8

FPS, PROTOTYPE

SURFACE CURRENTS

PLAN 8B

TIME-STEP 71



CONDITION PLAN 8B
SEICHE HEIGHT 0.6 FT

SCALES IN FEET

PROTOTPYE 0 150 300

MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B
TIME-STEP 91

CONDITION PLAN 8B
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B
TIME-STEP 111

CONDITION PLAN 8B WITH GAP CLOSED
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B (GAP CLOSED)
TIME-STEP 11

CONDITION PLAN 8B WITH GAP CLOSED
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

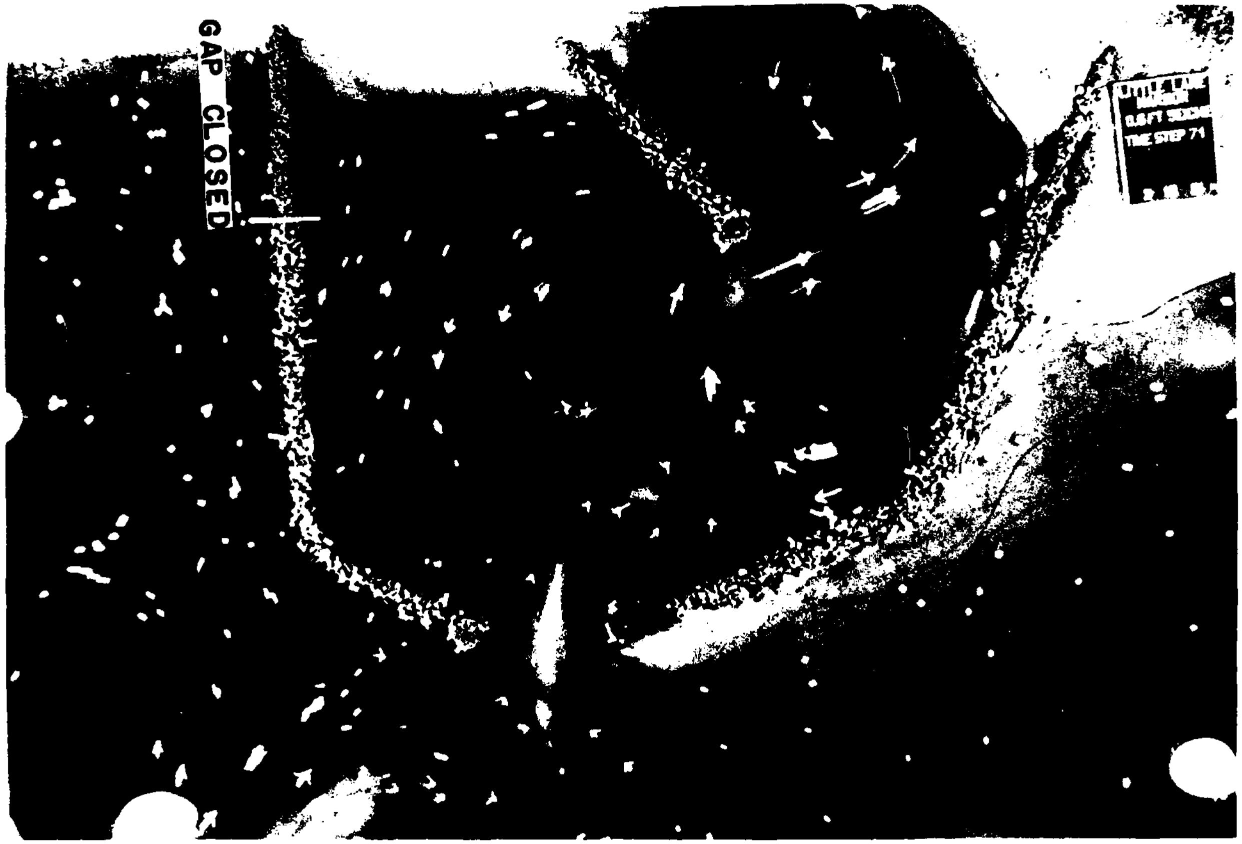
SURFACE CURRENTS
PLAN 8B (GAP CLOSED)
TIME-STEP 31

CONUITION PLAN 8B WITH GAP CLOSED
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B (GAP CLOSED)
TIME-STEP 51

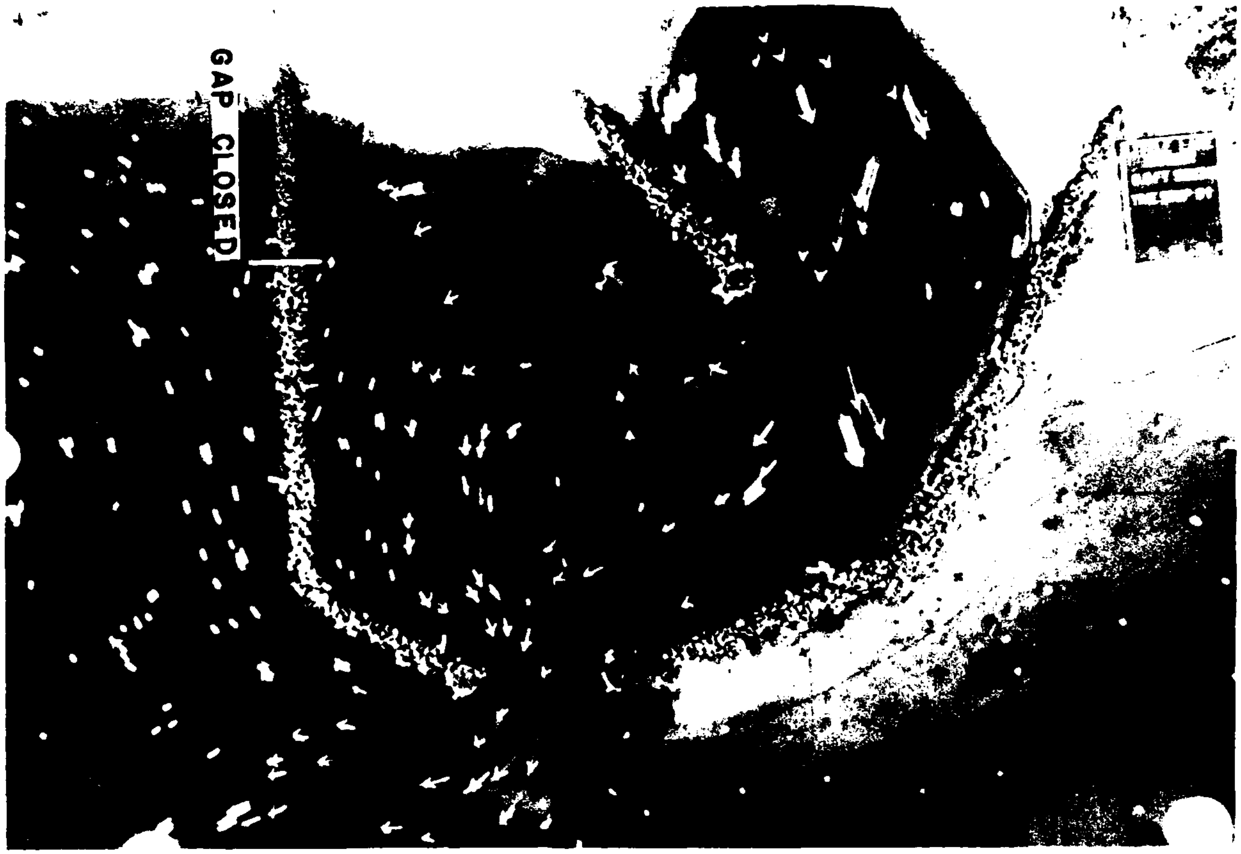


CONDITION PLAN 8B WITH GAP CLOSED
SEICHE HEIGHT 0.6 FT

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

SURFACE CURRENTS
PLAN 8B (GAP CLOSED)
TIME-STEP 71



CONDITION PLAN 9B WITH GAP CLOSED
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B (GAP CLOSED)
TIME-STEP 91

CONUITION PLAN 8B WITH GAP CLOSED
SEICHE HEIGHT 0.6 FT

SCALES IN FEET
PROTOTPYE 0 150 300
MODEL 0 2 4

VELOCITY SCALE
0 2 4 6 8
FPS, PROTOTYPE

SURFACE CURRENTS
PLAN 8B (GAP CLOSED)
TIME-STEP 111

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Seabergh, William C.
Prevention of shoaling at Little Lake Harbor, Michigan : Hydraulic Model Investigation / by William C. Seabergh, James W. McCoy (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. ; available from NTIS, 1982.
80 p. in various pagings , 293 p. of plates ; ill. ; 27 cm. -- (Technical report ; HL-82-16)
Cover title.
"July 1982."
Final report.
"Prepared for U.S. Army Engineer District, Detroit."
Bibliography: p. 67.

1. Harbors--Michigan. 2. Harbors of refuge. 3. Hydraulic models. 4. Little Lake Harbor (Mich.) 5. Shore protection. I. McCoy, James W. II. United States. Army. Corps of Engineers. Detroit District.

Seabergh, William C.
Prevention of shoaling at Little Lake Harbor : ... 1982.
(Card 2)

III. U.S. Army Engineer Waterways Experiment Station. Hydraulics Laboratory. IV. Title V. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; HL-82-16.
TA7.W34 no.HL-82-16